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BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL

NUMBER 93

SYSTEMS OF ELECTRICAL AND MAGNETIC UNITS

Papers Presented Before The American Section,
International Union of Pure and Applied Physics
Chicago, June 24, 1933

RICHARD T. GLAZEBROOK, HENRI ABRAHAM, LEIGH PAGE,
GEORGE A. CAMPBELL, HARVEY L. CURTIS
AND ARTHUR E. KENNELLY

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
OF
THE NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.
1933

Price $1.00

507.7
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Announcement Concerning Publications
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OF THE

NATIONAL RESEARCH COUNCIL

December, 1933 Number 93

SYSTEMS OF ELECTRICAL AND MAGNETIC UNITS

Papers Presented Before The American Section, International Union of Pure and Applied Physics Chicago, June 24, 1933

"Nat. research council [illegible] of physics section"

Richard T. Glazebrook, Henri Abraham, Leigh Page,
George A. Campbell, Harvey L. Curtis
and Arthur E. Kennelly

Published by The National Research Council
of
The National Academy of Sciences
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PREFACE

Diversity in symbols, units and nomenclature is one of the most annoying difficulties which impede the interchange of scientific ideas. To remove this difficulty, so far as is practicable, is therefore a very appropriate undertaking for international organizations, and the International Union of Pure and Applied Physics has made this one of its first aims. In 1931 the Union established a Committee on Symbols, Units and Nomenclature (SUN Committee), consisting of Sir Richard Glazebrook, Great Britain, Chairman; Professor Chas. Fabry, France; Professor W. H. Keesom, Holland; and Professor A. E. Kennelly, U. S. A.; with Dr. Ezer Griffiths, National Physical Laboratory, Teddington, England, as Secretary. On account of discussions which were already in progress in the International Electrotechnical Commission on electrical and magnetic units, the SUN Committee decided to give attention first to the question of such units.

The Division of Physical Sciences, National Research Council, acting as the American Section of the Union, has the responsibility of organizing American participation in the work of the international SUN Committee. A meeting of the American Section with such foreign guests as could attend was held at Chicago on June 24, 1933, and the program was planned to introduce the work of the SUN Committee. The group of invited papers presented at that meeting gives so authoritative a summary of the status of electrical and magnetic units that the National Research Council has considered it important to make them generally available as a basis for future progress. These papers are therefore printed in full in this Bulletin.

E. C. Crittenden, *Chairman*,
American Committee on Symbols,
Units and Nomenclature.

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MINUTES OF THE MEETING OF THE AMERICAN SECTION OF THE INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS WITH FOREIGN GUESTS

MANDEL HALL, UNIVERSITY OF CHICAGO, JUNE 24, 1933

The meeting was opened by Dr. R. A. Millikan, President of the International Union of Pure and Applied Physics, with brief remarks on the importance of symbols, units, and nomenclature and of the activities of the International Union of Pure and Applied Physics in this field.

Mr. E. C. Crittenden presided during the presentation of the following papers and the subsequent discussion, and requested Edward Bennett to act as the secretary of the meeting.

In the absence of Sir Richard Glazebrook, his paper, "A Note on the Activities of the Committee for Symbols, Units and Nomenclature of the International Union of Physics (S. U. N. Committee)," was read by Dr. Millikan.

The following papers were presented by their authors:

"Mathematical Considerations Underlying the Formulations of the Electromagnetic Equations and the Selection of Units," by Professor Leigh Page.

"A Definitive System of Units," by Dr. George A. Campbell.

"The Establishment and Maintenance of the Electrical Units," by Dr. Harvey L. Curtis.

In the absence of Professor Henri Abraham, Professor A. E. Kennelly presented a translation of Professor Abraham's paper on "Magnetic Units," after which Professor Kennelly abstracted his own paper on "Possible Extensions of the Existing International Series of Electrical Units (ohm, volt, ampere, coulomb, farad, joule, watt) into a Complete Absolute System."

The papers of Messrs. Curtis and Campbell, together with extensive tables of units included in Professor Kennelly's paper, were distributed in mimeographed form at the meeting. The papers of the last two authors (Campbell and Kennelly) contained tentative drafts of recommendations to the Symbols, Units and Nomenclature (SUN) Committee of the International Union of Pure and Applied Physics as expressing the sense of the Chicago Meeting, on June 24, 1933, of the American Association for the Advancement of Science, the American Physical Society, and the American Section of the International Union of Pure and Applied Physics.

The fairly brief discussion which followed after the presentation of all the papers was directed largely to these recommendations. The following actions were taken by show of hands. The estimated number present at the meeting was 150 and the estimated number voting from 30 to 40.

Dr. Kennelly presented recommendation 1 of his draft and after discussion it was adopted in the following slightly modified form:

Recommendation 1. In view of the long established use of the classical system of CGS electric and magnetic units, no change should at present be made in it, either as to rationalising, or otherwise.

In the discussion of recommendation 1, Professor Leigh Page suggested a reference to the merits of the Gaussian system, eventually presenting the suggestion in the following form, in which form it was adopted.

Recommendation 2. In the future the merits of the Gaussian CGS system should be given consideration.

Dr. Kennelly then presented the second of his proposals for consideration. It was first moved to strike out the last sentence of the proposal, this sentence reading,—" Of these two, the MKS system is preferred for consideration." The chairman announced the vote on this to be roughly a tie. It was then moved to adopt the proposal as presented. The motion prevailed and the third recommendation reads as follows:

Recommendation 3. The existing series of practical electrical units (ohm, volt, ampere, coulomb, farad, henry, joule, and watt) may advantageously be extended into a complete absolute practical system, either through the medium of the meter-kilogram-second (MKS), or through the centimeter-gram-seven (ten tonnes) and second (CGSS). Of these two, the MKS system is preferred for consideration.

Dr. Campbell moved the adoption of the recommendation numbered 3 which accompanied his paper, reading as follows:

The International Bureau, in cooperation with the National Bureaus, should fix the ohm at a value which will best conserve the existing commercial precision resistances of the world, and then invoke every means of stabilizing it at this precise value as the definitive ohm.

This motion did not prevail.

Upon motion of Dr. Campbell the following recommendation was then adopted.

Recommendation 4. That the American SUN Committee, which is to be formed, shall be requested to consider the objections to the use of the absolute ohm and the advantages which might be gained by the use of the International ohm in the practical system.

(NOTE.—While the resolution as adopted read as above, Dr. Campbell's proposal is better expressed by making the final phrases read as follows: "gained by fixing the ohm at a value which will best conserve the existing commercial precision resistances of the world." It was understood also that the proposed committee should consider this question before October, 1933, when the International General Conference on Weights and Measures is to meet.)

Meeting adjourned.

EDWARD BENNETT,
Secretary of the Meeting.

A NOTE ON THE ACTIVITIES OF THE COMMITTEE FOR SYMBOLS, UNITS AND NOMENCLATURE OF THE INTERNATIONAL UNION OF PURE AND APPLIED PHYSICS. (S. U. N. COMMITTEE)

Sir R. T. Glazebrook, K.C.B., D.Sc., F.R.S.
Chairman, International Committee on Symbols, Units and Nomenclature

I have been asked by Professor Millikan, President of the International Union of Pure and Applied Physics, to lay before the conference a note of the activities of the S. U. N. Committee, of which I am privileged to be the Chairman.

In the first place let me express my regret that circumstances have rendered it impossible to hold a meeting of the International Union at Chicago at which a formal report of the work of the S. U. N. Committee would have been presented. Up to the last moment we hoped that this would be possible and it was with very great regret that Professor Abraham, Secretary of the Union, and I found ourselves obliged to place the difficulties before the President and to accept his decision to hold at Chicago only a meeting of the American Section of the Union with such European visitors at might be attending the conference and desired to be present as guests.

Had this meeting been held one important item of the agenda would have been the report of the S. U. N. Committee; the following note, for which I alone am responsible, is intended to indicate the matters which would probably have been discussed in that report.

At the General Assembly of the International Union of Pure and Applied Physics at Brussels on July 12, 1931, a discussion took place on the definition of the *standard thermal unit.* In the course of that discussion it was clear that definitions of many other standards in use in physics were required and a small Committee consisting of Professor Kennelly, U. S. A.; Professor Fabry, France; Professor Keesom, Holland; and Sir Richard Glazebrook, Great Britain, was set up to deal generally with the subject of Symbols, Units and Nomenclature and to report to the International Union.

The Committee was given power to add to its numbers and to appoint its own Chairman.

Sir Richard Glazebrook was appointed Chairman and Dr. Ezer Griffiths undertook the duties of Secretary. At a meeting in London shortly afterwards Professor Abraham, Secretary of the Union, was asked to write to the national bodies represented on the Union, inviting them to nominate members to serve on the Committee. It was arranged also that the Committee, when discussing any special subject, would invite the assistance of experts cognizant of that subject, who would for that purpose become members of the Committee.

At the first meeting, July 12, 1931, the following recommendations to the General Assembly of the Union were approved:

(1) That the *unit of heat* when measured in units of energy be the *joule,* defined as equivalent to 10^7 ergs.

(2) That the *gram-calorie* is the amount of heat required to raise the temperature of one gram of water from 14.5° to 15.5° of the international scale of temperature.

Note on Proposition (2). According to existing measurements the gram-calorie is equivalent to 4.18_6 joules. The definition is consistent with the decision of the International Steam Tables Conference in 1929 to adopt as a unit suitable for their purpose an international kilo-calorie equivalent to 1/860 of an international kilowatt hour.

The relation between the international watt and the watt is given by 1 international watt = 1.00039 watts.

At the meeting of the S. U. N. Committee in London on September 22, 1931, cooperation with the Standards Committee of the International Electro Technical Commission—Professor Kennelly, Chairman—was arranged for and it was agreed generally to make electrical and magnetic units the first subject of investigation by the Committee. Accordingly, a questionnaire was drawn up and sent to the National Committees of the Union and to other parties interested.

The principal issues raised by the questionnaire related to (1) the basis on which to rest a connected account of electro-magnetic phenomena and (2) should μ, the permeability, be treated as a quantity having dimensions in mass, length and time or as a pure number.

The various national bodies were asked to reply by a certain date and much interesting information was obtained.

An Electrical Congress was held in Paris during July, 1932, and it was thought desirable to take the opportunity of the presence of electricians from many nations to hold an informal conference between representatives of the International Union of Pure and Applied Physics and of the National Committees of a number of countries. This took place on July 9; the conference was attended by representatives from

TABLE 1
Electromagnetic Units

Quantity designated	C. G. S. units			Practical units	
	Symbol	Defining equation	Name	Unit	Volt-ampere unit
Flux	Φ	$\frac{d\Phi}{dt} = -E$	Maxwell	10^8 maxwells	Volt-second
Magnetic induction or flux density	B	$\int BdS = \Phi$	Gauss	10^8 gauss	Volt-second per cm.^{2}
Magnetomotive force round a circuit	F	$F = 4\pi NI$	Gilbert = Oersted-cm	10^{-1} gilbert	$\frac{1}{4\pi}$ Ampere-turn
Magnetizing force or field strength	H	$\int H \cos \epsilon \, ds = F = 4\pi NI$	Oersted	10^{-1} oersted	$\frac{1}{4\pi}$ Ampere-turn per cm. of path of H
Permeability	μ	$\mu = \frac{B}{H}$	Permeability	10^8 gauss 10^{-1} oersted	Volt-second per cm.^{2} $1/4\pi$ Ampere-turn per cm. length of path of H

Belgium, France, Great Britain, Germany, Holland, Italy, Norway and the United States.

The following propositions were unanimously accepted by the conference:

(1) Any system of units recommended must retain the eight internationally recognized practical units, viz., joule, watt, coulomb, ampere, ohm, volt, farad and henry.

(2) The C. G. S. system of units is suitable for the physicist.

(3) A system of practical units, including the above eight quantities, can be derived from these by multiplying the C. G. S. unit by appropriate powers of 10.

An informal vote taken showed a majority in favor of the following:

(4) The system of magnetic units may be based on the following two methods as alternatives:

(a) The force between two elementary magnetic poles (coulomb).

(b) The force between two elements of current (ampère).

(5) B and H are quantities of different nature.

(6) The factor $4\pi/10$ should be retained in the definition of magnetomotive force.

The conference was quite informal, intended mainly to guide the S. U. N. Commission in the preparation of its report to the International Union of Pure and Applied Physics in Chicago.

The table on page 6 is an indication of the results which, with one exception,[1] were, I believe, generally accepted.

Some further details of the discussions which took place will be found in the paper on Electric and Magnetic Units by Sir R. T. Glazebrook, which appeared in the *Journal of the Institution of Electrical Engineers* for March, 1933.

Since this conference discussions have proceeded with a view to the preparation of a report to the International Union, and while complete unanimity has not been reached on all points it should, I think, be possible to draft a report which would secure very general adherence. Other questions of importance have been raised by members of the Committee and on some of these preliminary discussions have taken place.

---

[1] The exception relates to the use of the name "gauss" for the unit of magnetic induction.

A PROPOS DES UNITÉS MAGNÉTIQUES

Henri Abraham,
Professeur à la Sorbonne

INTRODUCTION

La question des unités et des dimensions en électromagnétisme a donné lieu à de très nombreuses discussions, qui tiennent en grande partie à quelques défauts de précision de notre langage scientifique, ou à des divergences dans les définitions adoptées plus ou moins explicitement par les différents auteurs.

Certains d'entre nous, par exemple, parlent de dimensions d'unités, d'autres de dimensions physiques, d'autres encore de dimensions des grandeurs physiques, ce qui ne va pas sans créer quelque confusion, puisque l'on désigne par une même expression des conceptions divergentes. Il semble cependant qu'une entente pourrait être réalisée dans cette question particulière des *dimensions* au moyen de définitions précises des termes employés: cela aurait l'avantage de nous dégager en partie de la confusion actuelle.

Une égale confusion règne aussi dans les mémoires et dans les traités scientifiques sur les définitions des grandeurs physiques elles-mêmes, et plus particulièrement des grandeurs qui interviennent en électricité. Pour les uns, l'Induction Magnétique est une certaine chose, mais d'autres auteurs attribuent le même nom à des grandeurs introduites d'une manière différente. Ce trouble est encore augmenté par le fait que si ces deux "*inductions magnétiques*" ne sont pas une seule et même chose mesurée successivement avec des unités inégales, ce sont, en tout cas, des quantités toujours exactement proportionnelles.

Nous ne sommes même pas absolument d'accord sur ce que chacun de nous entend par grandeurs de même espèce. Tout le monde est-il par exemple d'avis que la masse matérielle des objets est *une seule* espèce de grandeur qui se révèle à nous tantôt par ses propriétés d'inertie et tantôt par les phénomènes de gravitation? N'y a-t-il personne qui attribue encore ces deux manifestations à *deux* grandeurs différentes, la masse d'inertie et la masse de gravitation qui seraient simplement proportionnelles?

Les problèmes deviennent peut-être plus délicats encore dans le domaine de l'électricité, où nous étudions des phénomènes pour qui les corps matériels ne sont que des éléments accessoires, le rôle essentiel pouvant être joué par le milieu où ces corps se trouvent plongés, ce milieu fut-il le *vide pur*, dépouillé de tout corps matériel, auquel nous continuerions quand même à attribuer des propriétés électriques bien définies.

Certaines de ces propriétés du vide pur, qui ne sont pas modifiées par la présence de la matière, et qui, ainsi, ne sont pas susceptibles de variations en plus ou en moins, doivent-elles être considérées, néanmoins, au même point de vue que les autres " grandeurs " de la physique?

Bien que certaines des questions qui se posent ainsi puissent toucher aux fondements mêmes de notre connaissance du monde physique, nous pensons qu'il est possible d'en considérer, à part, quelques-unes susceptibles d'être examinées objectivement et d'une manière formelle de façon à arriver à un langage précis. C'est là notre excuse d'avoir repris *" ab ovo "* la théorie des " dimensions " dans l'exposé qui forme la première partie du présent travail.

PREMIÈRE PARTIE

LA THÉORIE DES DIMENSIONS

1. Mesures—Unités—Systèmes d'Unités.—On mesure une grandeur en la comparant à une grandeur de même espèce, bien déterminée, choisie comme *unité*. Pour l'exécution de cette comparaison, il faut disposer d'une méthode expérimentale permettant de dire que deux grandeurs de l'espèce considérée sont *égales*, ou que l'une d'elles est égale à la somme des deux autres. On peut alors déterminer le *rapport* de chacune de ces grandeurs à son unité. Ce rapport est la *mesure* ou *valeur numérique* de cette grandeur, correspondant au choix de l'unité adoptée.

Si l'on étudie un ensemble de N espèces différentes de grandeurs, on a besoin de choisir N unités. L'ensemble de ces N unités forme ce que nous appelons un *système d'unités*.

On a le droit de modifier les choix adoptés pour les N unités et, a priori, on peut les faire varier d'une manière absolument quelconque. L'ensemble de tous les systèmes d'unités possibles forme un nombre N fois infini de systèmes d'unités quand chacune de ces unités est choisie arbitrairement, indépendamment des autres, c'est-à-dire quand on ne s'impose aucune règle de coordination entre les unités des différentes espèces de grandeurs.

2. Règles de Coordination des Unités.—Les systèmes d'unités en usage sont tous basés sur des règles conventionnelles pour la coordination des unités des diverses grandeurs.

Presque toujours, et notamment en électricité, les règles de coordination consistent à convenir qu'une certaine loi expérimentale sera représentée dans le système d'unités considéré par une égalité dont la forme dépend, non seulement de la loi expérimentale en question, mais encore d'une convention arbitraire.

Prenons comme exemple la loi expérimentale des phénomènes d'induction. Des mesures de précision ont établi que les forces électromotrices d'induction sont proportionnelles à la vitesse de variation du flux magnétique. Si nous représentons par e et $-\frac{d\phi}{dt}$ les *mesures* (valeurs numériques) de ces deux quantités proportionnelles, nous pourrons toujours convenir de coordonner les unités de temps, de flux et de force électromotrice de telle manière que, *dans le groupe de systèmes d'unités considéré,* notre loi expérimentale soit correctement représentée par la formule:

$$e = -\frac{d\phi}{dt}$$

C'est en effet la règle la plus souvent adoptée.

Mais de nombreux auteurs (Hertz, Lorentz, etc.) préfèrent adopter une autre *convention* consistant à représenter la même loi expérimentale par cette autre formule:

$$e = -\frac{1}{c}\frac{d\phi}{dt}$$

dans laquelle ils font figurer la mesure "c" de la vitesse de propagation des ondes électriques dans le vide. Ils ont ainsi une coordination d'unités très différente, puisque maintenant le choix de l'unité de vitesse intervient dans la coordination des unités de temps, de flux et de force électromotrice.

Ces deux conventions, très différentes, sont aussi correctes l'une que l'autre, et aussi légitimes, mais il est visible que l'une comme l'autre renferme une part d'arbitraire, et il n'est absolument pas permis de dire que l'une ou l'autre soit la *véritable* formule, ou qu'elle exprime une relation nécessaire entre les *grandeurs* dont les *mesures* figurent dans ces formules.

Nous attachons une certaine importance aux remarques qui précèdent: elles ont, pensons-nous, l'intérêt de marquer que les problèmes que nous étudions ici sont seulement des questions de pure arithmétique, et n'ont rien à voir avec les idées que nous pouvons nous faire sur la nature intime des grandeurs physiques.

3. Groupes de Systèmes d'Unités Coordonnées—Unités et Grandeurs Fondamentales—Unités et Grandeurs Dérivées.—Considérons nos N espèces de grandeurs, et convenons de coordonner leurs N unités en nous conformant à N-P règles de coordination, indépendantes, compatibles et bien déterminées. L'ensemble de tous les systèmes d'unités qui respectent ces *N-P* règles sans être assujettis à aucune autre règle, constitue ce que nous appelons un *groupe de systèmes d'unités coordonnées.* Ce groupe comporte *P* indéterminées, autrement dit *P* variables indépendantes, puisque le choix des *N* unités est soumis à *N-P* conditions indépendantes.

Les *P* variables indépendantes de ce groupe de systèmes d'unités seront les unités de *P* grandeurs qui devront être convenablement choisies parmi les *N* grandeurs considérées, en tenant compte des règles de coordination adoptées.

C'est ainsi que, en électricité, on a été amené à constituer des groupes de systèmes d'unités comportant soit quatre, soit cinq, soit trois unités arbitraires indépendantes.

Les unités, variables indépendantes d'un groupe de systèmes d'unités, sont généralement désignées sous de nom d'*unités fondamentales,* ou *unités de référence.* Les autres unités sont dites *unités dérivées.*

On dit aussi, parfois, que les *Grandeurs* dont les unités sont considérées comme indépendantes sont les *Grandeurs Fondamentales* du groupe et que les autres sont des *Grandeurs Dérivées.* Il eût été préférable d'éviter cette manière de parler qui peut laisser croire à tort que l'on se préoccupe de la nature intime des grandeurs à un point de vue très élevé, alors qu'il ne s'agit que de questions arithmétiques très simples et tout à fait élémentaires.

4. Dimensions—Equations de Dimensions.—Comme nous le disions tout à l'heure, les règles de coordination d'unités consistent à s'imposer la forme sous laquelle on convient d'écrire les formules représentatives d'un certain nombre de lois physiques. On peut dire que ces égalités définissent le groupe de systèmes d'unités dont on s'occupe.

Dans les groupes de systèmes d'unités usités, il se trouve en fait que les égalités de définition sont des formules algébriques monomes: cela entraîne une conséquence importante. Si, en effet, les unités fondamentales, qui sont des variables libres, changent d'une manière quelconque, les unités dérivées qui en dépendent varieront elles-mêmes suivant des expressions algébriques monomes. Soient par exemple a, a'; b, b'; c, c' . . . . les valeurs successives des unités fondamentales correspondant aux grandeurs A, B, C . . . . , et u, u' les valeurs de l'unité dérivée pour les grandeurs d'espèce U; le passage du premier système d'unités au second entraînera pour les unités dérivées une relation de la forme

$$\frac{u'}{u} = \left(\frac{a'}{a}\right)^{\alpha} \cdot \left(\frac{b'}{b}\right)^{\beta} \cdot \left(\frac{c'}{c}\right)^{\gamma} \dots \quad (1)$$

Les nombres α, β, γ, ... qui sont entièrement déterminés par les équations de définition du groupe, sont ce que Fourier a appelé *exposants* *de dimensions* de l'unité dérivée dont il s'agit,[1] et l'égalité ci-dessus est *l'équation de dimensions* correspondante.

Depuis Fourier, l'usage a prévalu d'employer simplement le mot "dimensions" au lieu de "exposants de dimensions."

Ces nombres expriment simplement la manière dont les variations d'une unité dérivée dépendent des variations des unités fondamentales, quand on modifie celles-ci en respectant les équations de définition, c'est-à-dire en se conformant exactement aux *conventions* qui caractérisent le groupe de système d'unités que l'on considère.

Il est clair que les dimensions dépendent essentiellement de ces conventions, et qu'elles comportent ainsi, essentiellement, une part d'arbitraire. Remarquons, en particulier, que les dimensions peuvent changer quand on conserve les mêmes grandeurs fondamentales, en modifiant les conventions de définition des systèmes d'unités.

Notons encore que l'usage s'est introduit de dire que les nombres α, β, γ . . . . que nous venons de définir, sont les *dimensions de la grandeur U* par rapport aux grandeurs *A, B, C.* . . . . Cet usage nous paraît regrettable, puisqu'il s'agit non des *grandeurs* prises en elles-mêmes, mais seulement de leurs unités.

Par contre, il est extrêmement commode d'écrire l'équation de dimensions sous la forme abrégée et symbolique:

$$[U] = [A]^{\alpha} \cdot [B]^{\beta} \cdot [C]^{\gamma} \; . \; . \; . \; . \qquad (2)$$

dans laquelle on pousse même la simplification jusqu'à supprimer les *crochets* de cette notation symbolique.

La signification de cette forme réduite (2) de l'équation de dimensions n'est rigoureusement et strictement rien d'autre que la proposition de nature purement arithmétique traduite par la formule plus développée (1) que nous avons écrite au début du présent paragraphe.

5. Quelques Remarques.—Nous nous excusons d'insister aussi fortement sur le caractère "relatif" des dimensions (qui n'ont rien d'absolu); l'oubli de ce caractère a parfois causé beaucoup de confusion. Qu'on nous permette donc de répéter que l'équation (2) n'est qu'une image abrégée de l'équation (1), et ne saurait à aucun titre être considérée comme une *relation entre les grandeurs U, A, B, C,* . . . . elles-mêmes.

Dans le groupe des systèmes d'unités mécaniques classiques, par exemple, la relation symbolique $[F] = [M] \cdot [G]$ (équation des dimensions) ne signifie nullement qu'une force *est le produit d'une masse par une accélération,* d'autant que personne ne nous apprend la manière d'effectuer une telle multiplication.

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[1] Fourier, Théorie de la Chaleur, paragraphes 160 et suivants.

De la même manière, en électricité, la formule $e=ir$ qui représente en général la loi d'Ohm; ou bien l'équation de dimensions correspondante: $[E]=[I]\cdot[R]$ signifient uniquement que la différence de potentiel mesurée est proportionnelle à la fois à l'intensité du courant et à la résistance mise en jeu, et que, en outre, les unités de ces trois grandeurs ont été coordonnées, *par convention,* de manière que entre les mesures simultanées faites sur ces trois quantités, il existe exactement la relation arithmétique: $e=ir$.

Il n'est donc pas possible de dire qu'une différence de potentiel *EST le produit d'une intensité de courant par une résistance,* quand on veut attacher à cet énoncé la signification d'une multiplication de nature plus ou moins mystérieuse de ces grandeurs considérées en elles-mêmes.

Et cependant l'usage est constant d'énoncer cette proposition et tant d'autres analogues comme *" une résistance est une vitesse "* . . . . etc. Cela ne présente pas d'inconvénients si l'on est bien prévenu qu'il ne s'agit que d'abréviations et d'un langage excessivement *" elliptique "* ou condensé où les mots n'ont plus leur sens habituel.

Avec ces précautions oratoires (trop souvent sousentendues et . . . . oubliées) on pourra dire avec une même sérénité *qu'une résistance est une vitesse* ou bien l'*inverse d'une vitesse,* parce que l'on rétablira par la pensée tout ce qui a été supprimé pour arriver à ce langage ultra-condensé—qui peut alors rendre de grands services en raison même de son extrême condensation.

Encore une remarque:

La définition des " dimensions " exige la considération d'*un groupe* de systèmes d'unités, et *non pas d'un seul* système d'unités. Pour que l'on puisse parler de " dimensions," il faut d'abord que l'on ait fixé les règles de coordination d'unités caractérisant ce groupe; mais il faut aussi la *variabilité* des unités. Un système d'unités fixées une fois pour toutes, qui seraient susceptibles d'être représentées par des étalons matériels n'ayant rien de variable, ne saurait avoir de dimensions. Mais ce système particulier d'unités peut faire partie d'un *groupe,* et l'ensemble des systêmes d'unités de ce groupe comportera dés dimensions. Ce même système particulier d'unités peut aussi faire partie de plusieurs autres groupes dans lesquels les dimensions pourront changer d'un groupe à l'autre.

C'est ainsi que l'ensemble des unités mécaniques C. G. S. classiques: erg, dyne, gramme . . . . etc. forme un système d'unités bien déterminées et *invariables* pour lequel il n'y a pas à parler de dimensions, les dimensions s'introduisant seulement quand on considère le *groupe* des systèmes d'unités L. M. T. (et non plus C. G. S.) caractérisé par les règles de coordination d'unités bien connues, et où trois unités fondamentales sont des variables libres.

Et enfin une dernière remarque:

Supposons que l'une des conventions faites pour la coordination des unités du groupe considéré consiste en ce que dans tous les systèmes d'unités de ce groupe, il soit entendu que l'unité d'une certaine grandeur demeurera invariable, toujours la même dans tous ces systèmes d'unités. Alors, les dimensions de l'unité de cette grandeur, ou pour employer le langage courant, les dimensions de cette grandeur dans ce groupe de systèmes d'unités seront *zéro* par rapport à chacune des unités fondamentales.

Dans le groupe des systèmes d'unités électrostatiques, à trois unités fondamentales, où l'on a fait la convention *d'écrire la loi des attractions électriques dans le vide* sous la forme: $F=\frac{qq'}{r^2}$ ce que l'on exprime aussi parfois en disant que l'on convient de prendre le pouvoir diélectrique du vide comme unité de pouvoir diélectrique, les dimensions de cette dernière grandeur sont *zéro* par rapport aux trois unités fondamentales.

Précisons bien que c'est seulement quand on abandonne cette règle de coordination d'unités et que l'on introduit par exemple une variable de plus pour passer à un *groupe* à quatre variables que le pouvoir diélectrique peut retrouver des dimensions.

De même dans le groupe classique à quatre fondamentales dont nous reparlerons dans la Deuxième Partie, il n'y a pas de dimensions pour la propriété non dénommée que possèdent les courants de créer des champs magnétiques, parce que l'une des conventions de coordination consiste à dire que les unités devront être telles que le relation $\int (H, dl) = 4\pi i$ soit numériquement exacte. Mais quand on renonce à cette règle et que l'on forme un groupe de système d'unités à *cinq* unités fondamentales dans lequel la loi physique dont nous parlons est représentée par cette autre formule: $\int (H, dl) = \lambda i$, alors, la quantité λ qui correspond à cette propriété non dénommée possède des dimensions, bien que l'expérience semble montrer qu'il s'agisse d'une propriété indépendante de la présence de la matière.

6. Equations de Grandeurs.—On a proposé de donner le nom de "*équations de grandeurs*" (grossengleichungen) aux égalités en partie conventionnelles qui, traduisant une loi expérimentale, et écrites sous une forme convenue, servent à définir un groupe de systèmes d'unités.

Cette dénomination, si elle était adoptée, et si elle n'emportait avec elle aucune arrière-pensée, aurait l'avantage de donner un nom assez court à ces égalités.

Il n'y a là sans doute qu'une question de *mots;* j'avoue cependant que je n'aime pas ce terme *" équation de grandeurs "* précisément à cause du danger qu'il présente à l'égard des personnes insuffisamment prévenues (et dans l'enseignement) de laisser croire que ces équations seraient des relations entre les *" Grandeurs "* prises en elles-mêmes, dans un sens en quelque sorte métaphysique—et je préfère conserver l'expression beaucoup plus longue " égalités partiellement conventionnelles servant de définition à un groupe de systèmes d'unités coordonnées."—Au moins comme cela, je ne risque pas que mes elèves comprennent tout de travers ce que je désirais leur expliquer.

Insistons encore une fois, en prenant l'exemple des lois de l'induction. Nous avons déjà dit que, suivant les auteurs, on trouvait cette loi représentée par l'une ou l'autre des deux égalités:

$$e=-\frac{d\phi}{dt}, \quad e=-\frac{1}{c}\frac{d\phi}{dt}$$

Ni l'une ni l'autre ne peuvent être considérées comme une relation entre les *Grandeurs* elles-mêmes, puisque ces relations sont différentes et que s'il pouvait exister une relation entre des *Grandeurs* cette relation ne pourrait être que *unique.*

Les relations en question ne sont que des relations entre les *mesures* de grandeurs, dans des systèmes d'unités déterminés. Certaines personnes pourraient penser que la première de ces deux égalités serait seule *" vraie "* et donnerait la *" vraie "* relation entre les grandeurs, parce que l'on n'y fait pas figurer la vitesse *c,* qui, disent-elles, *ne devrait pas intervenir dans cette question.* La réponse est simple. *En nous plaçant au point de vue de ces personnes,* nous leur disons: nous ignorons complètement le processus physique qui intervient dans la production des forces électromotrices d'induction, et nous ne pouvons absolument pas savoir ce qui *" devrait "* ou *" ne devrait pas "* figurer dans la représentation algébrique des lois de l'induction; en particulier, nous ne savons pas du tout la manière dont on *" devrait "* faire apparaître pour la première fois la vitesse *c* qu'il faut bien arriver à faire figurer quelque part dans l'électromagnétisme.

7. Homogénéité des Formules.—Les égalités (en partie conventionnelles) qui servent à définir un groupe de systèmes d'unités coordonnées restent invariantes quand on fait varier les unités fondamentales pour passer d'un système d'unités à un autre système du même groupe. Si donc, dans un calcul quelconque on utilise correctement ces formules en les combinant par multiplication ou division, ou bien en combinant par addition et soustraction des égalités entre quantités de même espèce, on devra toujours obtenir des égalités qui demeureront exactes quels que soient les changements de systèmes d'unités, pourvu que l'on se maintienne dans le *groupe* défini dont il s'agit.

Les *mesures* que les lettres représentent dans ces formules varient en raison inverse des unités. Si donc on remplace chaque lettre de la formule par son monome de dimensions, tous les termes de l'égalité devront contenir des exposants égaux pour les symboles de chacune des unités fondamentales. Ecrites "*en dimensions*" les formules doivent, ainsi, être *homogènes* (au sens algébrique habituel) par rapport aux symboles de ces unités fondamentales.

L'utilisation des dimensions et de cette règle d'homogénéité comme moyen de contrôle de l'exécution correcte d'une série de calculs rend des services assez sérieux.

8. Le point de vue vectoriel et tensoriel.—Il serait tout à fait intéressant de restreindre l'arbitraire dans le choix des équations de définition d'un groupe de systèmes d'unités en s'imposant quelque condition concernant la nature vectorielle ou, plus généralement, tensorielle des grandeurs qui y sont représentées. Mais il ne semble pas que cela soit actuellement réalisé d'une manière générale et absolue. Il est assez dèlicat de décider, par exemple, si un élément de surface doit être considéré comme un scalaire ou comme un certain tenseur du second ordre. Il semble actuellement que l'introduction de la notation tensorielle ne puisse pas échapper à la nécessité de prendre comme point de départ, non seulement les faits d'expérience, mais encore, elle aussi, certaines *conventions* du genre de celles auxquelles nous faisons allusion.

Nous laissons donc cette question de la représentation tensorielle de côté en renvoyant le lecteur à un mémoire que M. Paul Langevin doit publier incessamment sur ce sujet.

Nous laissons également de côté la question très importante d'une représentation plus complète des "dimensions" par l'introduction des éléments de symétrie, ce qui correspond aussi à un aspect de la représentation tensorielle: notons seulement que la représentation d'un champ magnétique par un vecteur n'est pas correcte puisque la symétrie du champ magnétique est celle d'un corps de révolution centré tournant autour de son axe, et non pas celle d'une demi-droite.

9. Nombre des Grandeurs Fondamentales ou des Unités Fondamentales.—Le nombre des unités fondamentales des groupes de systèmes d'unités coordonnées n'est en rien imposé par la nature. Bien au contraire, ce nombre est essentiellement conventionnel, c'est-à-dire qu'il est en fait absolument arbitraire.

Le nombre des unités fondamentales (et par suite le nombre des grandeurs fondamentales) est en effet la différence entre le nombre des espèces de grandeurs considérées et le nombre des règles que l'on a adoptées pour la coordination des unités dans le groupe de systèmes d'unités que l'on a convenu de constituer.

Pour passer à volonté d'un groupe à P unités fondamentales à un groupe comportant une grandeur fondamentale de plus il suffit de supprimer l'une quelconque des règles de coordination d'unités que l'on s'était d'abord imposées. Inversement, on diminue d'une unité le nombre des grandeurs fondamentales en s'imposant telle nouvelle règle de coordination que l'on voudra, distincte des règles déjà acceptées.

Envisageons d'abord, par exemple, le groupe des systèmes d'unités électromagnétiques classiques, où l'on a adopté trois unités fondamentales (qui peuvent être celles de longueur, de masse et de temps). Ce groupe renferme parmi ses règles de coordination celle qui consiste à convenir que la loi d'action entre deux aimants placés dans l'une des positions dites de Gauss est représentée par la formule

$$\text{Couple} = \frac{M \cdot M'}{r^3}$$

Si nous supprimons cette règle, l'unité de Moment Magnétique cesse d'être coordonnée avec les unités mécaniques pour devenir une variable indépendante. On arrive ainsi au groupe des systèmes d'unités à quatre grandeurs fondamentales bien connu, et qui paraît être assez en faveur auprès de certaines personnes.

Mais on peut continuer. Partant de ce groupe de systèmes d'unités à quatre unités fondamentales, portons notre attention sur la formule classique, qui fait partie des formules de définition de ce groupe:

$$\int (H, dl) = 4\pi i$$

Elle correspond à une règle de coordination disant que les unités de courant, de longueur et de champ sont coordonnées de manière que cette formule soit vérifiée avec ces unités. Or nous sommes parfaitement libres de renoncer à cette règle de coordination d'unités. Nous aurons alors étendu davantage le groupe des systèmes d'unités envisagés. Ce sera maintenant un groupe à *cinq* grandeurs fondamentales, pour lesquelles on peut effectivement choisir les trois grandeurs mécaniques habituelles, longueur, masse, temps, et, en plus, une grandeur d'ordre électrique et une autre grandeur d'ordre magnétique, comme, par exemple, la perméabilité magnétique d'un côté et le pouvoir diélectrique de l'autre.

Disons encore, pour terminer ce sujet, que l'on peut parfaitement réduire à moins de trois le nombre des unités fondamentales sans trop faire appel à l'arbitraire.

Remarquons en effet que dans les groupes de systèmes d'unités mécaniques et électromagnetiques dont nous venons de parler, on a laissé complètement de côté les phénomènes de gravitation universelle, dont on feint systématiquement d'ignorer l'existence. Si donc on ajoute aux règles de coordination d'unités adoptées une règle supplémentaire concernant la manière d'écrire la loi de Newton, le nombre des unités fondamentales et des grandeurs fondamentales de la mécanique se trouvera ramené de trois à deux seulement—et l'on pourrait aller encore plus loin en faisant intervenir la vitesse de propagation des ondes dans le vide.

10. Un peu de discussion.—Quelques lecteurs seront peut-être peu satisfaits de la désinvolture avec laquelle nous venons de parler des *Grandeurs fondamentales.* C'est qu'en effet, il paraît exister une certaine tendance à mêler, plus qu'il ne conviendrait, les idées de *notions premières de notre entendement,* avec nos idées sur les grandeurs de la Physique ainsi qu'avec la question infiniment plus modeste, dont nous nous occupons ici, celle des systèmes d'unités.

Faisons d'abord remarquer, pour éviter tout malentendu, que nous avons eu soin de définir expressément la signification attribuée dans ce qui précède à l'expression " grandeurs fondamentales." Ce sont, avons-nous dit, les grandeurs dont les unités ont été choisies comme unités de référence (ou unités fondamentales) dans le groupe de systèmes d'unités considéré. Ces *grandeurs fondamentales* ne correspondent donc pas du tout à ce que nous pouvons concevoir de plus ou moins vague sur des grandeurs qui seraient des *notions premières* de notre entendement et auxquelles, en bonne logique, nous voudrions faire correspondre les " grandeurs fondamentales " des systèmes d'unités. C'est ce malentendu permanent, dû à une dualité du sens attribué aux mots, qui est la principale cause des discussions interminables sur la question qui nous occupe.

On nous excusera de considérer en conséquence, ces discussions comme de simples questions de mots sans grand intérêt scientifique, tout en insistant sur l'importance qu'il y a, précisément, à se mettre d'accord sur la signification exacte des termes que l'on veut employer.

DEUXIEME PARTIE

LES UNITÉS EFFECTIVEMENT UTILISÉES EN MAGNÉTISME

Les seules unités effectivement utilisées dans les mesures magnétiques semblent être exclusivement les unités C. G. S. électromagnétiques et les unités qui en dérivent; les unités dites électrostatiques ne sont je crois unités dites *pratique* qui en dérivent; les unités dites électrostatiques ne sont je crois jamais employées par ces mesures.

Par contre, on emploie fréquemment en électromagnétisme, avant toute application numérique, des formules algébriques que l'on combine dans divers calculs et qui ne sont correctes que moyennant des conventions sur les unités: ce sont des formules relatives à des groupes de systèmes d'unités à quatre unités fondamentales, ou à trois unités fondamentales dont nous allons d'abord rappeler la structure.

1. Le Groupe des Systèmes d'Unités (symétrique) à Quatre Variables.— C'est, à une nuance près (concernant le *déplacement* électrique) le groupe utilisé par Maxwell dans l'exposé de sa théorie électromagnétique de la lumière.

Ce groupe est défini par l'ensemble des conventions consistant à s'imposer de représenter les lois les plus importantes de l'électromagnétisme par les formules suivantes:

(1) Force entre charges électriques dans le vide: $F = \frac{qq'}{K_0 r^2}$.

(2) Champ électrique créé par une charge dans le vide: $h = \frac{q}{K_0 r^2}$.

(3) Différence de potentiel ou force électromotrice: $e = \int (h, dl)$ (produit scalaire).

(4) Energie: $W = eq$.

(5) Capacité: $q = Ce$.

(6) Intensité de courant: $i = \frac{dq}{dt}$.

(7) Résistance: $e = iR$.

(8) Champ magnétique: $4\pi i = \int (H, dl)$ (produit scalaire).

(9) Moment magnétique (Couple dans un champ normal): Couple $= M.H$.

(10) Action entre aiguilles aimantées dans le vide pour la position de Gauss: Couple $= \frac{MM'}{\mu_0 r^3}$.

(11) Induction magnétique dans le vide: $B = \mu_0 H$.

(12) Perméabilité magnétique rapportée au vide: $\mu = \mu_r \cdot \mu_0$.

(13) Flux d'induction: $\phi = \iint B_N dS$.

(14) Force électromotrice d'induction: $e = -\frac{d\phi}{dt}$.

(15) Force exercée dans le vide sur un élément de courant: $F = [B, idl]$ (produit vectoriel).

(16) Vitesse de propagation des ondes: $c = \frac{1}{\sqrt{K_0 \mu_0}}$.

Toutes ces conditions de coordination d'unités sont compatibles, sans être toutes indépendantes, leurs liens provenant notamment de l'application du principe de la conservation de l'énergie; de sorte qu'il reste quatre variables réellement indépendantes. Mais on a coutume d'utiliser ce groupe de systèmes d'unités comme s'il était en réalité à *cinq* grandeurs fondamentales. On conduit en effet en général tous les calculs en faisant abstraction de la dernière condition de coordination d'unités: $c = \frac{1}{\sqrt{K_0 \mu_0}}$ et c'est seulement en fin de calcul que l'on introduit cette condition.

Ayant ainsi ramené le groupe à avoir quatre grandeurs fondamentales, il est de tradition de conserver les trois grandeurs mécaniques: longueur, masse, temps, parmi les quatre fondamentales, et de prendre pour quatrième une grandeur de nature électrique pour laquelle on a proposé la charge électrique, ou bien la résistance en raison de la facilité de constituer des étalons pour cette dernière grandeur.

2. Les Sous-Groupes du Groupe Symétrique.—Si, dans le groupe à quatre variables on s'astreint à laisser constante la variable K_0, en ajoutant aux règles de coordination d'unités du paragraphe précédent la règle nouvelle de faire K_0 toujours égal à *un,* on constitue un groupe de système d'unités à trois unités fondamentales, qui sont généralement désignés par l'expression "systèmes d'unités L. M. T. électrostatiques," parce que l'on a l'habitude de prendre les unités de longueur de masse et de temps comme unités fondamentales.

On obtient d'une manière analogue le groupe des *systèmes d'unités L. M. T. électromagnétiques* en prenant, comme on dit, pour unité *conventionnellement invariable* de perméabilité, la perméabilité magnétique du vide, au lieu de prendre le pouvoir diélectrique du vide comme unité de pouvoir diélectrique.

Ce sont ces deux groupes de systèmes d'unités que Maxwell a envisagés et pour lesquels il a donné les dimensions en L. M. T. qui constituent le paragraphe 626 de son Traité d'électricité et de magnétisme.—Tandis que dans le paragraphe 623, il avait donné les dimensions des diverses unités électriques dans le groupe à quatre variables indépendantes de tout à l'heure, en exprimant ces dimensions d'abord en *L. M. T. e* puis en *L. M. T. m,* la quatrième unité fondamentale étant d'abord l'unité de charge électrique et ensuite l'unité de masse magnétique fictive.

3. Le Groupe de Systèmes d'Unités de Heaviside, Hertz, Lorentz.—C'est un groupe à trois unités fondamentales (longueur, masse, temps) dont les conditions de coordination d'unités ne diffèrent pas beaucoup des précédentes. On conserve l'ensemble des règles du groupe à quatre variables que nous avons indiquées, mais on écrit la loi de l'induction sous la forme:

$$e = -\frac{1}{c}\frac{d\phi}{dt} \quad \text{au lieu de} \quad e = -\frac{d\phi}{dt},$$

et l'on supprime la dernière condition $c = \frac{1}{\sqrt{K_0\mu_0}}$ en la remplaçant par les *deux* conditions simultanées

$$K_0 = 4\pi \quad \text{et} \quad \mu_0 = 4\pi.$$

Ces deux dernières conditions font disparaître le facteur 4π d'un certain nombre de formules, mais en le faisant apparaître dans d'autres qui sont *peut-être* un peu moins souvent employées.

D'autres auteurs emploient encore un groupe de systèmes d'unités légèrement différent, dans lequel les deux dernières règles de coordination d'unités consistent à prendre pour les lois d'attraction de coulomb les formes $F = \frac{qq'}{r^2}$ et $F = \frac{mm'}{r^2}$. C'est pour ce dernier groupe que l'on a dit parfois que les mesures électriques étaient supposées faites en unités électrostatiques tandis que les mesures magnétiques étaient faites en unités électromagnétiques.

4. Le Système C. G. S. Électrostatique et le Système C. G. S. Électromagnétique.—Si, dans les groupes de systèmes d'unités à trois variables L. M. T. (électrique ou magnétique) définis ci-dessus au paragraphe N° 2, on prend pour unités fondamentales le centimètre, le gramme-masse et la seconde, on obtient les deux systèmes C. G. S. classiques, dans lesquels toutes les unités sont entièrement déterminées.

L'un et l'autre de ces deux systèmes particuliers d'unités font partie d'une série de systèmes C. G. S. analogues, dont l'ensemble a peu à peu couvert toutes les sciences physiques.

Ces systèmes C. G. S. divers, reliés entre eux par les unités de base centimètre, gramme, seconde, ne sont sans doute pas d'une perfection absolue, mais *ils existent,* ils se sont répandus dans toute la science, et ce nous semblerait faire oeuvre vaine et oeuvre mauvaise que de tenter aujourd'hui de les modifier, même pour les améliorer, si tant est que les modifications proposées soient réellement des améliorations.

5. Le Système Électromagnétique Pratique.—Certaines des unités du système C. G. S. Électromagnétique ne sont pas très commodes pour les usages de la technique industrielle: elles sont trop grandes ou trop petites. Aussi a-t-on été conduit à employer, concurramment avec ce système C. G. S. un autre système d'unités pris dans le même groupe L. M. T. électromagnétique, dans lequel les unités fondamentales sont: pour la longueur, le *quadrant* qui vaut un milliard de centimètre (10^9 cm.) ; pour la masse le cent-milliardième de gramme (10^{-11} gr.) ; et pour le temps la seconde.

On peut dire aussi, ce qui est strictement équivalent, que les unités du système dit pratique sont des multiples ou sous-multiples décimaux exacts des unités C. G. S. électromagnétiques, choisis de manière que les équations fondamentales qui relient les mesures des grandeurs électriques restent les mêmes que dans le système C. G. S.

On arrive ainsi aur unités bien connues:

JOULE $=10^{7}$ *CGS; WATT* $=10^{7}$ *CGS; COULOMB* $=10^{-1}$ *CGS*
AMPÈRE $=10^{-1}$ *CGS; OHM* $=10^{9}$ *CGS; VOLT* $=10^{8}$ *CGS*
FARAD $=10^{-9}$ *CGS; HENRY* $=10^{9}$ *CGS*

L'Ampère, le Volt, le Farad, le Henry correspondent à des grandeurs pour lesquelles on peut réaliser des étalons bien définis et susceptibles de conservation. Aussi, a-t-on proposé d'employer des systèmes d'unités basés sur la valeur de tels étalons et non plus sur leurs définitions à partir des unités C. G. S.

Mais il se dessine maintenant un mouvement d'opinion inverse tendant à revenir aux définitions de ces unités pratiques comme *multiples* ou *sous-multiples décimaux exacts* des unités C. G. S.

Je considère, personnellement, une pareille décision comme absolument sage. Cela n'empêchera pas de continuer à se servir de résistances étalons ou de piles étalons, qui conserveront toute leur utilité et resteront parfaitement suffisantes, pour les besoins de la pratique, quand on n'aura pas à se rapprocher de la précision avec laquelle sont définies les unités fondamentales de longueur de masse et de temps.

6. Les Propositions Concernant le Changement des Unités Mécaniques Fondamentales.—Nous avons dit, et Maxwell avait déjà fait remarquer, que les huit unités électriques "pratiques": "*Joule, Watt, Coulomb, Ampère, Ohm, Volt, Farad, Henry,* peuvent être considérées comme des unités d'un système L. M. T. *électromagnétiques* ($\mu_0=1$) où les unités de longueur, de masse et de temps, sont le quadrant (10^{9} cm) le cent milliardième de gramme (10^{-11} gr) et la seconde.

Mais ce bloc des huit unités "pratiques" peut aussi être rattaché d'une infinité de manières à d'autres unités mécaniques, et l'on a suggéré de faire ce rattachement de telle sorte que l'on puisse adopter les nouvelles unités mécaniques de longueur, de masse et de temps, d'une manière universelle, pour toutes les mesures physiques, sans trop de gêne.

C'est ainsi qu'on a proposé notamment de prendre pour unités mécaniques fondamentales, le mètre, la tonne et la seconde en renonçant, bien entendu, à la convention électromagnétique $\mu_0=1$ pour lui substituer la convention $\mu_0=10^{-4}$—et l'on a encore suggéré le mètre, le kilogramme et la seconde avec $\mu_0=10^{-7}$, ce qui a, pour le moins, la conséquence singulière de faire représenter la perméabilité du fer par des nombres extrêmement petits.

Ces suggestions sont évidemment très intéressantes, mais, même en faisant abstraction de ce qu'elles conduiraient à prendre quelques unités fort peu pratiques, il nous semble que leur examen ne peut avoir aujourd'hui qu'un intérêt purement académique.

Ces suggestions, à notre avis, arrivent cinquante ans trop tard, il ne paraît plus possible de renoncer aux systèmes C. G. S. employés universellement comme systèmes de référence, dans tous les pays et pour toutes les sciences, et sur lesquels est établi tout l'échafaudage des données numériques expérimentales.

TROISIEME PARTIE

LES DIFFICULTÉS PARTICULIÈRES DE LA DÉFINITION DES GRANDEURS MAGNÉTIQUES

Nous arrivons maintenant à la partie la plus délicate de notre exposé. Alors que, jusqu'ici, nous avions rappelé des choses généralement bien connues, qui ne paraissent guère exposées à de sérieuses objections nous avons maintenant à dire quelles nous semblent être les causes des divergences de vues. Comme cela cesse d'être tout à fait objectif, il pourra peut-être y avoir davantage matière à contestation.

Nous voudrions cependant commencer par quelques observations sur lesquelles nous ne pensons pas qu'il y ait de désaccord: ces observations forment les paragraphes 1 à 5 de la dernière partie de notre exposé.

1. Les Lois d'Actions à Distance et le Rôle des Milieux Matériels.— Les anciennes théories du champ électromagnétique étaient basées sur des lois d'action directe à distance, lois de Coulomb pour les attractions entre charges électriques ou entre corps aimantés, lois d'action des courants sur les aimants ou sur les courants; tandis que les doctrines de Faraday et de Maxwell ont conduit à attribuer le rôle essentiel au milieu ambiant, alors même que ce milieu, dépouillé de toute matière, se réduirait au vide pur.

Si l'on a pu dire avec raison que la théorie de Maxwell consistait à écrire les équations du champ électromagnétique "*a priori*" en les considérant comme l'expression immédiate de lois naturelles, il n'en reste pas moins vrai qu'elles sont la généralisation des relations antérieurement admises en tant que conséquences des lois d'action à distance.

Il reste vrai aussi, malgré tout, que ces lois d'action directe à distance prises comme hypothèses de travail permettent de décrire d'une manière complète les phénomènes de l'électrostatique et de la magnétostatique.

Tout le monde est d'accord sur la manière dont cette description des phénomènes statiques peut être faite *quand le milieu ambiant est le vide.* Mais il n'en est plus de même quand de milieu ambiant est matérial.

Prenons d'abord le cas d'un milieu homogène dans lequel les phénomènes sont supposés proportionnels à ceux qui se produisent dans le vide. On trouve parfois énoncées pour ce cas ces propositions:

L'action entre deux charges électriques a pour valeur $F = \frac{qq'}{Kr^2}$ le coefficient K dépendant du milieu—et de même: l'action entre deux aiguilles aimantées a pour valeur (position de Gauss):

$$\text{Couple} = \frac{MM'}{\mu r^3}$$

le coefficient μ dépendant lui aussi du milieu.

Nous voudrions faire remarquer que ces propositions ne paraissent pas pouvoir être acceptées. Nous pensons qu'il est impossible de décrire les phénomènes au moyen de lois d'actions à distance dépendant du milieu. Une seule description est possible: il faut admettre que les lois d'attraction sont *indépendantes des milieux interposés.* Les attractions s'exercent, quel que soit le milieu, suivant la même loi que si ce milieu était le vide pur, et ces attractions se transmettent au travers de la matière, comme si la matière n'existait pas.

Qu'il soit impossible de donner une description complète avec des lois comportant un coefficient caractéristique du milieu, cela est évident dans le cas où le milieu n'est pas homogène: par exemple en magnétisme, quand une partie seulement du champ est occupée par des corps magnétiques.

En définitive, l'évaluation des forces exercées doit se faire de la manière suivante:

On calcule les attractions suivant la loi d'action *dans le vide,* en y ajoutant l'action des corps qui se sont aimantés (ou polarisés) par l'action du champ, calculée par la même loi, et l'on y ajoute encore l'effet des pressions hydrostatiques transmises par les milieux fluides dans lesquels les corps se trouvent plongés.[2] Il en est de même pour les actions des courants sur les aimants et pour les actions des courants entre eux, qui doivent toujours être calculées d'après les lois d'action *dans le vide,* en tenant compte des pressions hydrostatiques.

Nous devons donc considérer qu'il n'est possible de parler d'actions s'exerçant directement à distance qu'en se référant à une loi d'action *unique,* celle des attractions dans le vide, s'exerçant au travers des corps matériels comme si la matière n'existait pas.

Les coefficients de proportionnalité expérimentaux: pouvoir diélectrique et perméabilité magnétique n'ont de signification que dans la mesure où ils correspondent à des polarisations électrique ou magnétique proportionnelles aux champs qui les produisent, sans saturation ni hystérésis.

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[2] Voir par exemple A. Lienard, Ann. Phys. 20: 249 (1923).

Nous déduisons de ces remarques que l'observation des forces exercées sur les corps chargés, sur les aimants, sur les courants, décèle des propriétés indépendantes de la présence de la matière. Ce sont, si l'on veut, des propriétés universelles, correspondant à des *constantes universelles,* qui sont les coefficients d'attraction électrique, magnétique et électromagnétique dans le vide.

Ces trois coefficients universels des lois d'attraction doivent donc être placés sur le même rang, et nous n'avons pas le droit de dire " *les lois de Coulomb du magnétisme et de l'électrostatique dépendant du milieu tandis que d'action d'un courant sur un aimant est indépendante de ce milieu; nous devons considérer par conséquent les coefficients des deux lois de Coulomb comme des grandeurs physiques, mais nous considérons le coefficient de l'action d'un courant sur un aimant comme un nombre pur et non comme une grandeur physique."*

Non, ces trois coefficients doivent être traités de la même manière; ce sont ou ce ne sont pas des grandeurs physiques, comme vous voudrez, mais il faut prendre votre décision a la fois pour ces trois *propriétés spécifiques* du vide.

Remarquons toutefois que ces trois propriétés spécifiques du vide se réduisent très vraisemblablement à deux, si, comme tout nous porte à le croire, l'hypothèse des courants particulaires d'Ampère est conforme à la réalité. Les aimants étant formés de courants il n'y aurait à considérer que des attractions électriques et des actions entre courants.

Notons enfin que ces propriétés électromagnétiques spécifiques de l'espace vide se présentent maintenant à nous de la même manière que cette autre propriété de ce même espace vide de pouvoir transmettre les actions de gravitation universelle; les phénomènes de l'électromagnétisme et ceux de la gravitation rentrent dans les mêmes cadres.

2. L'Équivalence des Aimants et des Courants.—Les expériences d'Ampère montrent qu'un aimant est équivalent à certains courants. Cette équivalence est-elle indépendante des milieux extérieurs?

La réponse est affirmative, à la condition de spécifier l'équivalence de la manière suivante:

Considérons un aimant limité par une certaine surface, S. Imaginons que nous fassions le vide dans l'intérieur de cette surface fermée, et que nous y placions ensuite un système de conducteurs non magnétiques parcourus par divers courants. Le principe d'équivalence posé par

Ampère consiste en ceci qu'il est possible de trouver une distribution de courants telle que l'action à distance de ces courants à *l'extérieur de la surface S* soit identique à l'action de l'aimant. Cette équivalence se maintient quelle que soit la distribution de la matière,[3] magnétique ou non, à l'extérieur de cette surface *S;* étant bien entendu que cette surface limite *S,* continue à être *fermée,* au sens physique du mot, c'est-à-dire qu'on n'y laisse pénétrer aucun corps magnétique.

En particulier une *aiguille* aimantée à intensité d'aimantation uniforme est équivalente à un solénoïde, ou plutôt à une nappe de courant de densité uniforme enroulée sur un cylindre ayant la forme de l'aiguille aimantée, mais il faut considérer que ce cylindre est *fermé,* et qu'il n'y peut entrer aucun corps magnétique.

De même un *feuillet* magnétique est équivalent à un courant qui suivrait le contour du feuillet et cette équivalence persiste quelle que soit la distribution des corps magnétiques dans le champ. Toutefois, pour être strictement correct, il faut imaginer que l'on fait passer par le contour du feuillet une surface géométrique (d'ailleurs quelconque) qui constitue une *coupure* dans le champ.

3. Influence d'un Milieu Fluide Paramagnétique sur les Forces Magnétiques.—Les affirmations que nous allons présenter dans ce paragraphe sont admises en général, mais elles ne reposent à notre connaissance, sur aucune mesure, sur aucune observation.

En fait, ces affirmations résultent de l'hypothèse d'actions à distance s'exerçant suivant les lois qui conviennent au vide, complétées par le calcul, que nous indiquions plus haut, de l'effet d'une polarisation magnétique proportionnelle dans le milieu paramagnétique, et de l'effet des pressions hydrostatiques du milieu magnétique polarisé: tout cela est purement théorique.

Quoi qu'il en soit, *on admet* qu'en remplaçant le milieu non magnétique par un milieu paramagnétique, l'action d'une aiguille aimantée sur une autre aiguille aimantée est *divisée* par le coefficient de perméabilité magnétique du milieu (rapporté au vide)—que l'action entre courants ou entre feuillets est *multipliée* par ce coefficient—que l'action entre une aiguille aimantée et un courant (ou un feuillet) est indépendante de la présence du milieu magnétique—mais il n'y a rien de simple pour des aimants de forme quelconque.

Tout cela est conforme à ce que nous disions sur l'équivalence des courants et des aimants. Considérons, en effet, le solénoïde fermé équivalent à une aiguille aimantée, qui agit sur une autre aiguille aimantée. Si nous permettons au milieu extérieur de pénétrer dans ce solénoïde, ce qui lui constitue un noyau magnétique, son moment magnétique sera multiplié par la constante magnétique du milieu, puisqu'il faudra tenir compte de l'action à distance (suivant la loi du vide) du barreau aimanté constitué par ce noyau. L'action sur une aiguille aimantée, qui variait en raison inverse de la perméabilité, deviendra donc indépendante du milieu.

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[3] Dans la mesure, du moins, où la présence de corps ferromagnétiques à l'extérieur de la surface limite S ne réagit pas d'une manière appréciable sur l'intensité d'aimantation de l'aimant donné.

On verrait de même qu'en permettant au milieu de pénétrer en même temps dans deux solénoïdes équivalents à deux aiguilles aimantées, leur action mutuelle se trouvant multipliée deux fois par ce même coefficient, deviendrait bien proportionnelle à ce coefficient luimême, alors qu'elle variait en raison inverse de la perméabilité quand les solénoïdes étaient *fermés* ou remplacés par les aiguilles aimantées équivalentes.

4. Relation entre la Puissance d'un Feuillet et l'Intensité du Courant Équivalent.—Le moment magnétique M d'un feuillet est proportionnel à sa surface et à sa *puissance* p. Tout le monde est d'accord pour coordonner les unités de ces trois grandeurs de manière que l'on puisse écrire entre leurs *mesures* la relation

$$M=p\cdot S$$

Le courant I équivalent à ce feuillet agit comme le ferait un aimant ayant le même moment magnétique M que le feuillet. Mais l'action de ce courant ne dépend que de sa surface S et de son intensité I. Le moment magnétique M du courant est proportionnel à sa surface S et à son intensité I, comme il était proportionnel, tout à l'heure à la surface S et à la puissance p du feuillet; et l'équivalence des deux organes agissants, aimant ou courant, est complète, absolue, indépendante de toute contingence, telle que la nature des milieux interposés.

Il devrait dès lors être absolument normal de coordonner les unités du magnétisme avec celle de l'intensité d'un courant de manière que les *mesures du moment magnétique du courant* de sa surface et de son intensité soient reliées par la formule:

$$M=IS$$

ce qui entraînerait entre la puissance du feuillet et l'intensité du courant équivalent la relation générale:

$$p=I \tag{1}$$

C'est effectivement ce que fait Maxwell dans toute son étude du champ électromagnétique, jusqu'au paragraphe 615 de son Traité, au moment où il dit: "pour pouvoir employer à volonté le système des mesures électrostatiques ou celui des mesures électromagnétiques, nous conserverons le coefficient μ_0, nous souvenant que sa valeur est l'unité dans le système électromagnétique."

Dans le système d'unités à quatre variables indépendantes qu'il établit alors, Maxwell change les règles de coordinations d'unités qu'il avait adoptées, et comme il dit, il "*conserve le coefficient* μ_0," mais, à vrai dire, il introduit ce coefficient dans les formules de telle manière que la relation entre la puissance d'un feuillet et l'intensité du courant équivalent soit représentée par la formule:

$$p=\mu_0 I \tag{2}$$

L'introduction du facteur μ_0 dans cette formule a donné lieu à une protestation de Clausius qui en demandait la suppression en se référant, à la notion des courants particulaires d'Ampère. Le mémoire de Clausius provoqua une polémique où intervint, en particulier Sir Joseph Thomson,[4] qui montra que la formule (2) était une conséquence des points suivants:

Le champ d'un courant *est* l'action exercée sur un pôle magnétique unité.

L'intégrale de ligne du champ magnétique *est* $\int (H, dl) = 4\pi i$.

La force entre les deux pôles magnétiques *est* $F = \dfrac{mm'}{\mu_0 r^2}$.

Nous avons à dessein souligné trois fois le mot *est* parceque nous pensons au contraire, que l'on ne doit considérer dans tout ceci que des *conventions arbitraires.*

Nous sommes dans le cas actuel en présence de deux formules:

$$p=I \quad \text{et} \quad p=\mu_0 I$$

de même que, pour les lois de l'induction, nous nous étions trouvés en présence de deux formules:

$$e=-\frac{d\phi}{dt} \quad \text{et} \quad e=-\frac{1}{c}\frac{d\phi}{dt}.$$

Dans ce dernier cas, nous avions dit que les deux formules pouvaient aussi bien l'une que l'autre être adoptées comme règles de coordination des unités. Nous devons donc dire la même chose pour le cas de l'équivalence des courants et des feuillets; et l'une ou l'autre des deux formules peut effectivement être adoptée pour définir un groupe de système d'unités.

Mais pour l'équivalence des feuillets et des courants, il y a quelque chose de spécial, qui est important et mérite que nous lui consacrions un paragraphe particulier.

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[4] Thomson, J. J. Phil. Mag. (5) 13: 427 (1882).

5. A propos des Grandeurs qui sont de même Espèce.—Il est incontestable que nous avons le droit de choisir arbitrairement toutes les unités que nous utilisons.

Mais cet arbitraire doit cependant être limité par la condition de *ne pas choisir des unités différentes pour des grandeurs de même espèce.* On irait à la confusion la plus grande si l'on opérait ainsi.

Or c'est la question qui se pose de la manière la plus nette pour l'équivalence d'un feuillet magnétique et d'un courant. Nous sommes pris dans les mâchoires d'un dilemme:

Ou bien nous voulons rester dans l'ignorance de la raison de cette équivalence, et alors nous sommes très libres—ou bien nous estimons que *nous savous* la raison de l'équivalence, et *nous savons* que les aimants sont formés par de véritables courants. Alors nous ne sommes plus libres, et *nous devrions* n'introduire que le courant et sa surface pour représenter le feuillet. Notre attitude devrait donc être celle-ci: la constante universelle μ_0 *ne doit pas* figurer dans notre règle de coordination d'unités parce qu'elle n'intervient pas dans le mécanisme de l'équivalence mécanisme que *nous connaissons.*[5]

Certes, il n'est pas encore *certain* que l'hypothèse des courants particulaires d'Ampère soit l'expression de la réalité, bien que cela devienne de plus en plus vraisemblable. Nous n'avons donc pas encore le droit de dire que les conventions qui conduisent à écrire la condition d'équivalence sous la forme: $p=\mu_0 I$ soient inadmissibles. Mais cette formule est inquiétante, et dans l'état actuel des choses, puisque tout n'est, dit-on, que question de probabilités, disons qu'*il y a gros à parier* que les équations classiques qui définissent le groupe des systèmes d'unités à quatre variables de Maxwell paraîtront bientôt inadmissibles en ce qui concerne ce point particulier de l'équivalence entre courants et feuillets et par conséquent dans tout ce qui a trait aux formules du magnétisme.

Ce même risque d'être inadmissibles en ce qui concerne les unités magnétiques, existe encore tout entier pour les équations de définition du groupe de systèmes d'unités L. M. T. à trois variables indépendantes dits systèmes électrostatiques.

Par contre, dans le groupe de systèmes d'unités L. M. T. dits électromagnétiques, les équations de définition sont irréprochables au point de vue qui nous occupe, puisqu'elles conduisent à écrire la condition d'équivalence sous la forme $p=I$ qui ne se prête pas aux objections soulevées par Clausius.

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[5] Nous renvoyons le lecteur à un travail que M. Liénard publiera prochainement sur ce sujet.

Il convient de rapprocher ce que nous venons de dire pour les feuillets et les courantes de ce que l'on fait effectivement pour les différences de potentiel et les forces électromotrices:

Les phénomènes de l'électrostatique nous font connaître des différences de potentiel. D'autre part, les phénomènes d'induction nous donnent dans les circuits induits un certain " *quelque chose* " qui ressemble tellement, par ses propriétés, aux différences de potentiel de l'électrostatique que nous n'hésitons pas à identifier ce " *quelque chose* " avec une grandeur de même espèce qu'une différence de potentiel et nous mesurons ce " quelque chose " *avec la même unité,* que les différénces de potentiel.

De même, parce que nous voyons des charges apparaître et disparaître par le passage des courants de conduction, nous n'hésitons pas à dire qu'un courant électrique et un débit d'électricité sont des quantités de même espèce. Et pourtant les courants de Maxwell (courants de déplacement) ne correspondent pas, à proprement parler, au passage de charges électriques, et encore moins à des débits de ces électrons négatifs ou positifs ou de ces protons que nous avons tendance à considérer comme les supports nécessaires des charges électriques.

6. Combien doit-on compter d'Espèces différentes de Grandeurs en Électromagnétisme?—C'est la question du champ et de l'induction magnétiques qui va se poser ici.

Il est permis de remarquer tout d'abord que si l'on examine toutes les études des électrotechniciens, il ne s'agit jamais d'autre chose que de phénomènes *mécaniques,* ou du moins de phénomènes qui se traduisent par des recettes et des dépenses *d'énergie.*

Or le théorème de Poynting donne tout ce qu'il est nécesaire de connaître à ce point de vue puisqu'il nous renseigne complètement sur les quantites d'énergie qui entrent dans un domaine donné ou qui sortent de ce domaine.

Mais le vecteur de Poynting est entièrement défini, en chaque point, quand on se donne le champ électrique et le champ magnétique. Nous sommes donc en droit d'affirmer que la connaissance de ces *DEUX* seuls éléments est indispensable pour la connaissance de l'état électromagnétique du milieu à l'endroit considéré—du moins au point de vue énergétique.

D'un autre côté, les définitions habituelles qui conduisent aux notions classiques sur les grandeurs électriques pêchent un peu par la base.

Quand on parle de la force exercée sur un pôle magnétique, on ne nous dit pas *qui* fait la mesure—par rapport à quel système de référence les observations sont faites. Or les grandeurs électriques et magnétiques que l'on doit considérer comme définissant l'etat magnétique du milieu, devraient correspondre à des éléments indépendants du systéme de référence: ce devraient être des *invariants* dans les changements de systèmes de référence.

Mais dans la transformation de Lorentz-Einstein, il n'apparaît que *deux* invariants, d'une part, la densité *d'action* (différence entre la densité d'énergie électrique et la densité la d'energie magnétique) et, d'autre part, le produit scalaire des deux champs. Ici, encore, nous retrouvons *deux* comme nombre des éléments caractéristiques pour définir à la fois l'etat électrique et l'etat magnétique du milieu.

Malgré la valeur de ces arguments, et bien que la définition de Kelvin et de Maxwell que nous rappelons plus loin permette de considérer l'induction et le champ comme des grandeurs de même espèce, est-on réellement en droit de conclure en refusant d'envisager en électricité et en magnétisme de chaque côté, deux grandeurs d'espèces différentes, un champ et une induction? L'état électromagnétique d'un point du milieu devrait alors être défini par quatre grandeurs au lieu de deux.

On fait valoir en effect, non sans raison, que partout, en énergétique, les quantités d'énergie s'expriment toujours par le produit de deux facteurs: force et déplacement, charge et différence de potentiel . . . . champ magnétique et variation d'induction magnétique: cet argument n'est pas le moins du monde négligeable.

Mais, pour tenir la balance égale, il nous faut pourtant remarquer que, en gravitation universelle, on peut comme en électricité ou en magnétisme admettre que l'énergie potentielle est localisée dans le milieu ambiant, et cependant, à côté du *champ* de la gravitation, on na trouve aucun élément physique qui corresponde à une induction.

7. La Définition des Grandeurs Magnétiques à l'extérieur des corps aimantés.—Le lecteur qui aura eu la patience de nous suivre jusqu'ici reconnaîtra notre constante préoccupation de ne pas procéder par des affirmations basées sur des habitudes de langage ou sur des équivoques. Il paraît en effet indispensable de faire abstraction de ce que nous croyons savoir et surtout de ce que nous avons l'habitude de répéter par tradition—et, au contraire, de reprendre toutes choses par le début en supposant que nous sommes en présence des faits expérimentaux, sans aucune idée préconçue, comme serait un tout jeune étudiant qui viendrait de répéter une foule d'expériences de précision et pour qui nous chercherions à dégager des notions définies de tout cet ensemble expérimental.

C'est cet effort *de définition* que nous allons tenter—en nous limitant aux notions de " champ magnétique " et d'induction magnétique.

a. Forces exercées sur un Élément de Courant placé dans le Vide.—L'expérience montre qu'en chaque point de l'espace on peut déterminer un élément orienté ayant la symétrie d'une rotation à l'aide duquel la force exercée sur l'élément de courant peut être représentée par la formule numérique

$$F = a_1 [B_1, idl] \quad \text{(produit vectoriel)}$$

le " vecteur " B_1 représente (partiellement) l'élément orienté; le facteur a_1 dépend du choix des unités employées pour les mesures, chaque grandeur ayant été mesurée au moyen d'une unité de même nature. Nous voici donc en présence de la définition complète d'une première grandeur magnétique représentée par B_1.

b. Forces électromotrices d'Induction dans le Vide.—D'autre part et d'une manière *entièrement indépendante* des expériences utilisées dans l'alinéa ci-dessus, la mesure des forces électromotrices d'induction conduit à reconnaître l'existence d'un autre élément orienté, de même symétrie que le précédent et qui est tel que le flux ϕ de son vecteur représentatif B_2 permet le calcul des f.e.m. induites par la formule

$$e = a_2 \frac{d\phi}{dt} \quad \text{avec} \quad \phi = \iint (B_2)_N dS$$

On constate d'autre part que les deux vecteurs représentatifs B_1 et B_2 ont même orientation, qu'ils sont en toutes circonstances exactement proportionnels. Ils ne sont donc pas linéairement indépendants et l'on constate qu'ils ont entre eux la relation numérique

$$a_1 B_1 = a_2 B_2$$

L'ensemble de ces constatations constitue une remarquable vérification du principe de la conservation de l'énergie.

Nous voici donc maintenant en présence de *deux* grandeurs magnétiques. Le fait que ces deux grandeurs sont proportionnelles ne prouve pas qu'il s'agisse d'une seule et même grandeur, pas plus (ni moins) que la proportionnalité des masses d'inertie aux masses de gravitation ne permet d'identifier ces deux espèces de masses.

c. Action sur une aiguille aimantée.—En chaque point du champ, l'action sur une aiguille aimantée permet de définir une nouvelle grandeur ayant un vecteur représentatif B_3 tel que l'on puisse écrire l'égalité numérique

$$\text{couple} = a_3 [M \cdot B_3] \quad \text{(produit vectoriel)}$$

La troisième grandeur ainsi définie se trouve encore proportionnelle aux deux précédentes avec la même symétrie mais rien ne permet de l'identifier avec les précédentes ni de dire qu'il s'agit d'une grandeur d'espèce différente.

d. Polarisation Rotatoire Magnétique.—Si l'on place en un point quelconque du champ un petit tube contenant une solution concentrée d'iodure de mercure et d'iodure de potassium, orienté dans la direction la plus favorable, ce liquide acquiert le pouvoir rotatoire, et la mesure des rotations optiques définit un nouveau vecteur B_4, représentatif de l'état magnétique en ce point, de telle sorte que l'on peut écrire la relation (vectorielle)

$$\text{rotation} = a_4 B_4$$

où la constante numérique a_4 dépend, comme de juste, des unités choisies.

e. Biréfringence Magnétique.—L'observation de la biréfringence magnétique permet de définir une cinquième grandeur magnétique et de lui faire correspondre un cinquième vecteur B_5 encore proportionnel aux quatre précédents.

f. On définirait aisément un nouveau vecteur B_6 en faisant appel aux mesures de précision faites sur le phénomène de Zeeman.

Les six vecteurs B_1, B_2, B_3, B_4, B_5, B_6, ont même direction, les quatre phénomènes magnétiques sont proportionnels—et rien ne permet d'affirmer ou de nier que l'un quelconque soit " de même espèce " que l'un des autres. La polarisation rotatoire magnétique met particulierement bien en évidence les caractères de symétrie de l'état magnétique du champ.

g. Propriétés Mathématiques des Vecteurs B_1 B_2 B_3 B_4 B_5 B_6.—Ces six vecteurs sont définis pour chaque point de l'espace qui ne se trouve pas occupé par de la matière. Ils sont proportionnels et les mesures faites prouvent que l'un quelconque d'entre eux B, satisfait aux conditions suivantes:

(1) En régime permanent, ce vecteur B dérive d'un potentiel V, c'est-à-dire qu'il existe une fonction V des coordonnées telle que l'on puisse écrire les égalités numériques

$$B_x = \frac{\partial V}{\partial x} \qquad B_y = \frac{\partial V}{\partial y} \qquad B_z = \frac{\partial V}{\partial z}$$

(2) Le flux du vecteur B est conservatif, c'est-à-dire que l'on a

$$\text{div. } B = \frac{\partial B_x}{\partial x} + \frac{\partial B_y}{\partial y} + \frac{\partial B_z}{\partial z}$$

ou encore

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

Cette condition entraîne que le vecteur B peut aussi être défini par une famille de potentiels vecteurs U (F, G, H) tels que l'on ait

$$B_x = \frac{\partial G}{\partial z} - \frac{\partial H}{\partial y} \qquad B_y = \frac{\partial H}{\partial x} - \frac{\partial F}{\partial z} \qquad B_z = \frac{\partial F}{\partial y} - \frac{\partial G}{\partial x}$$

h. Relation entre les six vecteurs B et les Courants.—Si le champ électromagnétique est créé uniquement ***par des aimants,*** le potentiel V de l'un de ces vecteurs B est ***uniforme,*** il n'a qu'une valeur en chaque point, ce point se trouvant nécessairement à l'extérieur des aimants. S'il y a aussi des courants, on constate que le potentiel V n'est pas uniforme, que chaque circuit de courant est une ligne singulière et que l'intégration de la différentielle de V le long d'un circuit fermé C donne pour résultat numérique:

$$\int_C dV = \int_C B_x dx + B_y dy + B_z dz = \beta \iint_S J_N dS$$

L'intégrale $\int_S J_N dS$ représente la totalisation des densités de courant J projetées sur la normale aux éléments dS d'une surface S limitée par le circuit C;—le facteur β dépend du choix des unités et il n'y a aucune raison de le faire égal à 4π.

Lorsque le champ est exclusivement créé par des courants, l'ensemble des propriétés indiquées montre que l'on peut calculer le potentiel V en tout point de l'espace extérieur aux conducteurs traversés par les courants au moyen de la formule:

$$V = V_1 + V_2 \;.\;.\;.\; + V_k + \;.\;.\;.$$

avec

$$V_k = i_k \Omega_k \cdot \frac{\beta}{4\pi}$$

formule dans laquelle Ω_k est l'angle solide sous lequel le courant i_k est vu par l'observateur placé au point pour lequel on calcule le potentiel V.

Nous voyons donc bien que l'une ou l'autre des six espèces de grandeurs auxquelles nous avons fait correspondre $B_1 \;.\;.\;.\;.\; B_6$ peut être évaluée au moyen de ces formules.

i. Emploi d'une méthode de Zéro pour les mesures.—Soit à faire une mesure en un point A que nous supposons encore dans le vide ou dans un milieu non magnétique. Plaçons en ce point un petit tube cylindrique sur lequel nous enroulons une nappe de courants qui circulent perpendiculairement aux génératrices du tube. En disposant convenablement de l'orientation du tube et de l'intensité de la nappe de courants on arrive à annuler (à compenser) l'état magnétique au point A. A ce moment, ***les six manifestations*** de cet état magnétique que nous avons signalées disparaissent ***toutes les six*** en même temps, et la densité superficielle de la nappe de courant est proportionnelle aux valeurs de l'un ou de l'autre des six vecteurs B qu'elle a permis d'annuler en même temps.

La légitimité de cette méthode de mesure résulte des propriétés mathématiques énumérées un peu plus haut. Mais il est manifeste que cette méthode de zéro n'apporte aucun éclaircissement sur la question de savoir si les six vecteurs B sont ou ne sont pas identiques, sont ou ne sont pas de même espèce puisqu'elle s'applique indifféremment à l'une ou l'autre des six "*grandeurs*" B_1 . . . . B_6 que nous avons définies.

En d'autres termes, quand nous faisons une mesure par cette méthode de zéro, il nous est impossible de dire si nous avons mesure une grandeur d'espèce B_1, B_2 . . . . ou B_6 si nous avons mesuré une induction, un champ magnétisant . . . . ou tout autre chose.

8. L'État Magnétique dans l'intérieur des Corps Aimantés.—Nous ne pouvons apporter aucun instrument de mesure au sein de la masse d'un aimant d'acier ni dans l'intérieur d'un corps magnétique solide, et nous sommes réduits à ne pouvoir émettre que des suppositions vraisemblables sur ce qui s'y passe.

Dans le cas des corps paramagnétiques ou diamagnétiques, liquides ou gazeux, on pourrait placer des instruments de mesure en un endroit quelconque et procéder à des expériences.

Mais, jusqu'ici *aucune mesure* n'a été faite avec une précision suffisante pour permettre de déceler directement avec sécurité quoi que ce soit qui distingue la manière d'être du champ électromagnétique dans ces milieux magnétiques fluides de ce qu'elle serait dans le vide.

On a lieu de penser que les perturbations apportées aux propriétés du vide par la présence de ces corps serait de l'ordre de grandeur du cent-millième, c'est à dire vers la limite de sensibilité des expériences.

Les propriétés magnétiques de ce genre de corps se révèlent seulement par le fait que si on les place dans un champ magnétique, ils sont attirés vers les champs forts (ou repoussés par eux) comme la limaille de fer est attirée par l'aimant. Ces liquides et ces gaz se conduisent comme s'ils s'aimantaient dans le champ.

On sait cependant que les expériences de mesures faites sur les forces auxquelles ces corps sont ainsi soumis, s'interprètent correctement en admettant qu'il se produit 1°) une aimantation proportionnelle au champ (vecteur B_1, B_2, B_3, B_4, B_5 ou B_6) et 2°) que les aimants massifs ainsi produits sont soumis aux mêmes lois d'attraction que des aiguilles aimantées *placées dans le vide.* Il faut toutefois tenir compte de ce que des pressions hydrostatiques (calculables) se développent dans les fluides en question et que l'on doit tenir compte de l'action de ces pressions sur les parois des corps solides qui y sont immergés, comme nous l'avons rappelé au paragraphe 3.

Finalement, nous ne savons rien de plus sur ce qui se passe dans les liquides ou dans les gaz magnétiques que sur ce qui se passe réellement en un point de la masse à l'intérieur d'un aimant en acier au cobalt: il nous faut nous résigner à ne faire que des théories conjecturales.

9. Les théories des Phénomènes Magnétiques dans l'intérieur des Corps Aimantés.—Une théorie complète a été donnée par Kelvin et Maxwell. Ces auteurs emploient des unités " *electromagnétiques.*"

L'attraction entre " poles magnétiques " est donc représentée avec leurs unités par la formule: $F = \frac{mm'}{r^2}$. Le "*Champ*" est défini par l'action sur un pôle magnétique, mesurée dans l'intérieur d'une cavité allongée dans le sens de l'intensité d'aimantation. *L' " Induction"* est définie comme étant *le champ* mesuré dans une cavité plate perpendiculaire à l'aimantation. C'est donc, *par définition,* une quantité *de même espèce* que le " champ."

Ces deux grandeurs, champ et induction de *Maxwell-Kelvin,* sont ainsi, toutes deux, de l'espèce que nous avons représentée par B_3; et elles se confondent identiquement pour des mesures faites dans le vide.

Il a été donné d'autres définitions de l'" Induction." Pour les uns, l'Induction se mesure par les forces électromotrices qui donnent naissance aux courants induits.—Cela correspond à ce que nous représentons par les vecteurs B_2.

Pour d'autres, la définition dérive de la mesure de la force exercée sur un élément de courant, ce qui correspond aux vecteurs B_1.

Mais, dans l'une et l'autre de ces définitions, la mesure est supposée faite soit dans le vide, c'est-à-dire, pour les corps magnétiques, dans une cavité plate *vidée de matière* et orientèe perpendiculairement à l'aimantation, *comme dans la définition de Maxwell.*

En ce qui concerne le " *champ,*" nous connaissons d'abord la définition de Kelvin-Maxwell: action sur un pôle d'aimant unité, ou ce qui revient au même, action sur une aiguille aimantée (ce que nous avons représenté par les vecteurs B_3).

On a proposé, d'autre part, une définition du "*champ*" basée sur la méthode de compensation ou de zéro, signalée plus haut: Une nappe de courants de forme cylindrique allongée est disposée de manière à produire cette compensation, et la densité de courant de la nappe donne la mesure du " champ." Mais, dans le cas des corps magnétiques, la compensation ne peut être observée que si la nappe cylindrique est placée dans une cavité vidée de matière et allongée dans le sens de l'aimantation, comme dans la théorie de Maxwell.[6]

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[6] Il n'y a évidemment pas lieu de retenir la proposition consistant à définir le vecteur champ par l'*unique* condition représentée par la formule $\int (H, dl) = 4\pi i$. Qu'il nous suffise de remarquer qu'avec cette définition simpliste, un aimant ne créerait aucun champ autour de lui: il est indispensable de donner une définition expérimentale et *locale*.

Il serait alors tout aussi correct de dire que le courant compensateur fournit une mesure de l'*induction* dans cette cavité.

Nous voyons ainsi qu'il semble n'y avoir à considérer que deux définitions du champ: ou bien l'action sur un pôle magnétique, ou bien la définition par la méthode de " compensation." Mais puisque la constatation de la " compensation " est nécessairement faite *dans le vide,* cette dernière définition est d'une ambiguité complète: Comme nous l'avons déjà dit la compensation a lieu quelle que soit la nature de la grandeur sur laquelle on porte son attention; et il est impossible de savoir si la grandeur mesurée correspond à l'un ou à l'autre des vecteurs B_1 . . . . B_6—et il nous est *impossible de décider* si cette methode de zéro mesure une quantité *d'espèce différente* de celles que l'on aurait antérieurement définies comme *induction*—ou bien une quantité de même espèce.

10. Avant de conclure.—En résumé nous disposons pour le moins d'une demi douzaine de procédés pour définir une grandeur pouvant caractériser l'état magnétique en un point de l'espace.

L'exactitude de la théorie de Maxwell-Kelvin prouve qu'*il suffit* d'envisager *une seule* espèce de grandeur pour faire complètement la description des phénomènes.

Mais il est loisible d'en considérer deux, trois . . . . et par exemple, de définir séparément le champ et l'induction comme on vient de le dire et d'affirmer à volonté que ces deux grandeurs ne sont pas de même espèce ou qu'elles sont de même espèce. Ce n'est pas une question de physique expérimentale, c'est une question d'opinion métaphysique: il est impossible à l'heure actuelle de donner pour ou contre ces opinions d'autres arguments que de vagues raisons de sentiment.

En tout cas, ce n'est pas dans la théorie des dimensions qu'il faut chercher ces arguments pour ou contre: comme nous l'avons longuement expliqué dans la première partie de ce travail, les " dimensions " ne peuvent rendre que le reflet des *conventions arbitraires,* sur lesquelles elles sont établies et ne peuvent *rien* donner dans l'un ou l'autre sens.

CONCLUSIONS

Arrivé au terme de cette trop longue étude, je n'ose pas formuler de conclusions autres que celles d'une extrême prudence: Conserver provisoirement l'état actuel des choses; provoquer des réunions entre physiciens et techniciens, dans lesquelles on arrivera progressivement à se mettre d'accord, et surtout éviter des décisions hâtives que le hasard d'un vote pourrait entraîner.

Qu'il me soit permis cependant de dire quelles conséquences me semblent résulter de cette étude :

1° Les dimensions des grandeurs physiques comportent toujours, dans leur définition, une part de conventions arbitraires, et ces dimensions ne sont pas des caractères spécifiques de la nature des grandeurs.

2° Une même grandeur physique peut ainsi avoir des dimensions ou n'en pas avoir, suivant les conventions faites arbitrairement pour les coordinations d'unités.

3° Il ne paraît pas désirable de renoncer au système C. G. S. comme système universel d'unités mécaniques de référence.

4° En dehors de la définition de *Kelvin-Maxwell* pour le champ et l'induction, il n'existe aucune définition correcte d'un ensemble de deux grandeurs (champ et induction) pour caractériser l'état magnétique en un point d'un champ électro-magnétique, qui permette de dire si ces grandeurs sont ou ne sont pas de même espèce.

MATHEMATICAL CONSIDERATIONS UNDERLYING THE FORMULATION OF THE ELECTROMAGNETIC EQUATIONS AND THE SELECTION OF UNITS

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In discussing the relative advantages of different systems of electric and magnetic units there has been a tendency to ignore the effect of the choice of units on the form of the electromagnetic equations. To the theoretical physicist, who uses the complete set of equations, the form of these equations is of more concern than the selection of a set of convenient units to use with them. On the other hand, the attention of the engineer is largely directed to those equations involved in circuit theory, and consequently his interest has been concerned more with the conveniences of definitions and of units than with the simplicity of form of the fundamental equations.

The present situation is deplorable in that so many different systems of units are in common use, and, worse yet, different formulations of the electromagnetic equations. The English still adhere to the electrostatic and the electromagnetic units of Maxwell and the two corresponding sets of asymmetrical equations, whereas in Europe and to a considerable extent in this country the symmetrical Heaviside-Lorentz or the Gaussian equations are employed. The electrical engineers, on the other hand, have been giving consideration to new systems of units and new formulations of the electromagnetic equations designed to meet their own requirements. Unfortunately, in attempting to fulfill these requirements, they have lost sight of some of the criteria most important to the physicist.

The most desirable situation would be one in which a single set of electromagnetic equations was accepted by both physicists and engineers, the former using c.g.s. units therewith and the latter practical units. This situation exists at present in so far as Maxwell's electromagnetic set of equations is in use, but so many objections to this formulation of the fundamental equations exist (in particular their asymmetry and the inconvenient magnitudes of the practical units of mass and length) that they cannot be said to provide a satisfactory solution of the problem. In fact it seems impossible to satisfy the essential criteria of both the physicist and the engineer with a single set of equations. Therefore it is necessary to consider separately the requirements of the physicist and those of the engineer and the means by which these requirements can be met. There is, however, *one* general criterion which any satisfactory formulation of the electromagnetic equations should satisfy.

The form of the electromagnetic equations should be such as to exhibit the symmetry existing between electric quantities on the one hand and magnetic quantities on the other. This *criterion of symmetry* means that the numerical values and the physical dimensions of the coefficients of corresponding quantities in corresponding fundamental equations should be the same. The advantages of a symmetrical formulation of the fundamental equations are the following:

(1) All derived equations are symmetrical in electric and magnetic quantities. For example the energy density in symmetrical Heaviside-Lorentz units is

$$u=\frac{\kappa}{2}E^2+\frac{\mu}{2}H^2,$$

whereas in Maxwell's asymmetrical electromagnetic units

$$u=\frac{\kappa}{8\pi c^2}E^2+\frac{\mu}{8\pi}H^2,$$

where c is the ratio of the electromagnetic to the electrostatic unit of charge. As a result of symmetry all theoretical work is simplified, the number of different coefficients being halved in any equation involving corresponding electric and magnetic quantities.

(2) Corresponding electric and magnetic quantities have the same physical dimensions in the fundamental units. For instance, electric charge and magnetic charge are both of dimensions $[M^{1/2}L^{3/2}/T]$ in symmetrical Gaussian units, while electric charge is of dimensions $[M^{1/2}L^{1/2}]$ and magnetic charge of dimensions $[M^{1/2}L^{3/2}/T]$ in Maxwell's asymmetrical electromagnetic units.

(3) In transforming from one set of fundamental units to another, the transformation factors are the same for corresponding electric and magnetic quantities. Thus the number of different factors which must be tabulated or learned is only half as great for a symmetrical set of fundamental equations as for an asymmetrical set. Thus in the symmetric Heaviside-Lorentz equations the c.g.s. unit of electromotive force is 1063 volts, and the c.g.s. unit of magnetomotive force is the same multiple of the practical unit. With an asymmetrical set of equations, however, the factors are different.

(4) The definitions of corresponding electric and magnetic quantities correspond arithmetically. Thus, in the symmetrical Gaussian set of equations, a unit charge is that charge which repels a like equal charge at unit distance with unit force, and the same definition holds for unit pole, whereas in Maxwell's asymmetrical electromagnetic equations the e.m.u. of charge is that charge which repels a like equal charge at unit distance with force c^2, while the definition of unit pole is identical with that supplied by the Gaussian equations.

Denoting quantities measured in electromagnetic units by the subscript *m*, Maxwell's electromagnetic set of fundamental equations assumes the form

$$\nabla\cdot\mathbf{D}_m=\rho_m \quad (1),\qquad \nabla\cdot\mathbf{B}_m=0 \quad (2),$$

$$\nabla\times\mathbf{E}_m=-\dot{\mathbf{B}}_m \quad (3),\qquad \nabla\times\mathbf{H}_m=4\pi(\dot{\mathbf{D}}_m+\rho_m\mathbf{v}) \quad (4),$$

$$\mathbf{D}_m=\frac{\mathbf{E}_m}{4\pi c^2}+\mathbf{P}_m=\frac{\kappa}{4\pi c^2}\mathbf{E}_m \quad (5),\qquad \mathbf{B}_m=\mathbf{H}_m+4\pi\mathbf{I}_m=\mu\mathbf{H}_m \quad (6),$$

$$\mathbf{F}=\rho_m\{\mathbf{E}_m+\mathbf{v}\times\mathbf{B}_m\} \quad (7),$$

where κ and μ are the pure ratios representing respectively the permittivity and the permeability relative to vacuum. Comparing (3) with (4) and (5) with (6) it is seen that these equations are asymmetrical as regards every coefficient of corresponding terms in corresponding equations. It would be impossible to formulate a set of fundamental equations which fail more completely to meet the criterion of symmetry and to present the advantages which symmetry implies.

Provided we agree to retain the usual definitions of **E** and **H**, **P** and **I**, the most general transformation which we can make must be subject to the relations

$$\rho\mathbf{E}=\rho_m\mathbf{E}_m,\quad \sigma\mathbf{H}=\sigma_m\mathbf{H}_m,$$

$$\frac{\mathbf{P}}{\rho}=\frac{\mathbf{P}_m}{\rho_m},\quad \frac{\mathbf{I}}{\sigma}=\frac{\mathbf{I}_m}{\sigma_m},$$

where σ is the fictitious magnetic charge density $-\nabla\cdot\mathbf{I}$. Hence we are at liberty to introduce four arbitrary constants which may be dimensional. Without loss of generality we may put

$$\rho_m=\frac{\alpha}{c}\rho,\quad \sigma_m=\beta\sigma,\quad \mathbf{D}_m=\frac{\gamma}{4\pi c}\mathbf{D},\quad \mathbf{B}_m=\delta\mathbf{B},$$

the particular choice of factors being designed to make the equations symmetrical in c and 4π. Then the fundamental equations become

$$\nabla\cdot\mathbf{D}=4\pi\frac{\alpha}{\gamma}\rho \quad (1),\qquad \nabla\cdot\mathbf{B}=0 \quad (2),$$

$$\nabla\times\mathbf{E}=-\frac{1}{c}\alpha\delta\dot{\mathbf{B}} \quad (3),\qquad \nabla\times\mathbf{H}=\frac{1}{c}\beta\gamma\dot{\mathbf{D}}+\frac{4\pi}{c}\alpha\beta\rho\mathbf{v} \quad (4),$$

$$\mathbf{D}=\frac{1}{\alpha\gamma}\,\mathbf{E}+4\pi\frac{\alpha}{\gamma}\,\mathbf{P}=\frac{\kappa}{\alpha\gamma}\,\mathbf{E}\ \ (5),\qquad \mathbf{B}=\frac{1}{\beta\delta}\,\mathbf{H}+4\pi\frac{\beta}{\delta}\,\mathbf{I}=\frac{\mu}{\beta\delta}\,\mathbf{H}\ \ (6),$$

$$\mathbf{F}=\rho\left\{\mathbf{E}+\frac{\alpha\delta}{c}\,\mathbf{v}\times\mathbf{B}\right\}\ \ (7).$$

$$K=\alpha^2\frac{q_1q_2}{\kappa r^2},\quad [q]=\left[\frac{M^{1/2}L^{3/2}}{\alpha T}\right],$$

where there are included in addition to the electromagnetic equations themselves the expression for the electrostatic force K between two point charges q_1 and q_2 obtained from (1), (5) and (7), and the dimensional equation for charge q. Maxwell's electrostatic set of asymmetric fundamental equations is obtained by setting $\alpha=1$, $\gamma=4\pi$, $\beta=\delta=c$.

Now, if we are to satisfy the criterion of symmetry, comparison of (3) with (4) shows that $\alpha\delta=\beta\gamma$ and of (5) with (6) that $\alpha\gamma=\beta\delta$ as well, that is, $\beta=\alpha$, $\delta=\gamma$. Consequently the most general form which a symmetrical set of fundamental equations can assume is

$$\nabla\cdot\mathbf{D}=4\pi\frac{\alpha}{\gamma}\rho\ \ (1),\qquad \nabla\cdot\mathbf{B}=0\ \ (2),$$

$$\nabla\times\mathbf{E}=-\frac{1}{c}\,\alpha\gamma\dot{\mathbf{B}}\ \ (3),\qquad \nabla\times\mathbf{H}=\frac{1}{c}\,\alpha\gamma\dot{\mathbf{D}}+\frac{4\pi\alpha^2}{c}\,\rho\mathbf{v}\ \ (4),$$

$$\mathbf{D}=\frac{1}{\alpha\gamma}\,\mathbf{E}+4\pi\frac{\alpha}{\gamma}\,\mathbf{P}=\frac{\kappa}{\alpha\gamma}\,\mathbf{E}\ \ (5),\qquad \mathbf{B}=\frac{1}{\alpha\gamma}\,\mathbf{H}+4\pi\frac{\alpha}{\gamma}\,\mathbf{I}=\frac{\mu}{\alpha\gamma}\,\mathbf{H}\ \ (6),$$

$$\mathbf{F}=\rho\left\{\mathbf{E}+\frac{\alpha\gamma}{c}\,\mathbf{v}\times\mathbf{B}\right\}\ \ (7).$$

Having established the most general *symmetrical* formulation of the electromagnetic equations, we are now in a position to consider what particular values should be assigned to the two arbitrary constants α and γ in order to meet the requirements of the physicist and of the engineer. As the requirements of the physicist are less stringent than those of the engineer, we shall consider them first.

Next to *symmetry*, the physicist desires *simplicity* in the coefficients of the equations which he uses. Nevertheless he favors proposals which involve the minimum departure from the conventions and definitions to which he has become accustomed. As he is most often concerned with fields in empty space, he gives preference to a formulation which makes **D** identical with **E** and **B** with **H** when no material medium is present.

The greatest simplicity of the general symmetrical equations is achieved either (1) by making $\alpha=\sqrt{1/4\pi}$ and $\gamma=\sqrt{4\pi}$ or (2) by making $\alpha=\sqrt{c/4\pi}$ and $\gamma=\sqrt{4\pi c}$. The first gives us the Heaviside-Lorentz equations, used by Lorentz in his Lehrbuch der Physik, his Theory of

Electrons and other works, and used increasingly by recent writers in theoretical physics. This set of equations has the form

$$\nabla\cdot\mathbf{D}=\rho \quad (1), \qquad \nabla\cdot\mathbf{B}=0 \quad (2),$$
$$\nabla\times\mathbf{E}=-\frac{1}{c}\dot{\mathbf{B}} \quad (3), \qquad \nabla\times\mathbf{H}=\frac{1}{c}(\dot{\mathbf{D}}+\rho\mathbf{v}) \quad (4),$$
$$\mathbf{D}=\mathbf{E}+\mathbf{P}=\kappa\mathbf{E} \quad (5), \qquad \mathbf{B}=\mathbf{H}+\mathbf{I}=\mu\mathbf{H} \quad (6),$$
$$\mathbf{F}=\rho\left\{\mathbf{E}+\frac{1}{c}\mathbf{v}\times\mathbf{B}\right\} \quad (7).$$

Except for the factor $1/c$ appearing in (3), (4) and (7), every coefficient is unity. The displacement and conduction currents in Ampère's law (4) appear with the same coefficient, which is a great simplicity. Finally, in empty space $\mathbf{D}=\mathbf{E}$ and $\mathbf{B}=\mathbf{H}$.

The second alternative gives the equations recently suggested by Kennelly. They are

$$\nabla\cdot\mathbf{D}=\rho \quad (1), \qquad \nabla\cdot\mathbf{B}=0 \quad (2),$$
$$\nabla\times\mathbf{E}=-\dot{\mathbf{B}} \quad (3), \qquad \nabla\times\mathbf{H}=\dot{\mathbf{D}}+\rho\mathbf{v} \quad (4),$$
$$\mathbf{D}=\frac{1}{c}\mathbf{E}+\mathbf{P}=\frac{\kappa}{c}\mathbf{E} \quad (5), \qquad \mathbf{B}=\frac{1}{c}\mathbf{H}+\mathbf{I}=\frac{\mu}{c}\mathbf{H} \quad (6),$$
$$\mathbf{F}=\rho\{\mathbf{E}+\mathbf{v}\times\mathbf{B}\} \quad (7).$$

These are equally simple, but they fail to make $\mathbf{D}$ identical with $\mathbf{E}$ and $\mathbf{B}$ with $\mathbf{H}$ in empty space. Furthermore, unlike the Heaviside-Lorentz equations, they have no established place in physical literature. Hence of the two, the Heaviside-Lorentz equations are to be preferred.

Both the Heaviside-Lorentz and the Kennelly equations require definitions of many of the electromagnetic quantities different from those given by Maxwell. Thus the force between two charges is

$$K=\frac{q_1q_2}{4\pi\kappa r^2}$$

in the Heaviside-Lorentz equations and

$$K=\frac{cq_1q_2}{4\pi\kappa r^2}$$

in Kennelly's.

The set of symmetrical equations which departs least from Maxwell's usage are the Gaussian equations used extensively in Germany. These are obtained by making α and γ both unity. They are

$$\nabla\cdot\mathbf{D}=4\pi\rho \quad (1), \qquad \nabla\cdot\mathbf{B}=0 \quad (2),$$
$$\nabla\times\mathbf{E}=-\frac{1}{c}\dot{\mathbf{B}} \quad (3), \qquad \nabla\times\mathbf{H}=\frac{1}{c}(\dot{\mathbf{D}}+4\pi\rho\mathbf{v}) \quad (4),$$
$$\mathbf{D}=\mathbf{E}+4\pi\mathbf{P}=\kappa\mathbf{E} \quad (5), \qquad \mathbf{B}=\mathbf{H}+4\pi\mathbf{I}=\mu\mathbf{H} \quad (6),$$
$$\mathbf{F}=\rho\left\{\mathbf{E}+\frac{1}{c}\mathbf{v}\times\mathbf{B}\right\} \quad (7).$$

The electric quantities appearing in these (with the exception of **D**) are identical with those in Maxwell's electrostatic system and the magnetic quantities with those in his electromagnetic system. However the coefficients are less simple than in the Heaviside-Lorentz equations and the displacement and convection currents in Ampère's law appear with different coefficients. Probably the experimental physicist would prefer the Gaussian equations to the Heaviside-Lorentz, while the theoretical physicist would favor the latter over the former. The general adoption of either would mark a great advance over the present situation in which a large number of scientists in English-speaking countries still adhere to Maxwell's asymmetric formulation of the fundamental equations.

The requirements of the electrical engineer include in addition to those of the physicist certain criteria determined by the existence of established electrical standards.

First, it is essential to him that the system of units employed should include the eight internationally recognized practical units: joule, watt, coulomb, ampere, volt, ohm, farad and henry.

Second, it is important to him that the fundamental units to be used with these electrical units should be decimal multiples of the gram, the centimeter and the second. In fact, the pairs joule, watt and coulomb, ampere demand the retention of the second as the unit of time. The units of mass and length, then, are the only variables at our disposal, and they should be of more convenient magnitudes than the eleventh-gram and the earth-quadrant demanded by Maxwell's electromagnetic system.

Third, it may be desirable to the engineer that the standard of resistance be fixed arbitrarily without being subject to change as a result of more accurate determinations of the absolute ohm in future. This is due to the fact that comparisons of resistances can be determined to one part in a million, whereas there is little prospect that the absolute value of the ohm can be measured to better than ten parts in a million in the near future.

Let us consider the first of these three criteria. If we designate the practical units of mass and length by the subscript p, we have

$$[M_p]=\bar{\phi}[M]=\bar{\phi}\text{ gm.},\quad [L_p]=\bar{\theta}[L]=\theta\text{ cm.}$$

Now if $\bar{\phi}$ and $\bar{\theta}$ are given values such as to make the joule the unit of energy and the coulomb the unit of charge the six remaining internationally recognized practical units assume automatically the desired values. This follows from the fact that each of the six quantities involved is *defined* in terms of energy U and charge q or in terms of other quantities already defined in terms of these two, plus of course, time t, the unit of which has been retained unaltered; thus, power, $P = U/t$; current, $i = q/t$; potential or e.m.f., $V = U/q$; capacitance, $C = q/V$; resistance, $R = V/i$; inductance, $L = V/-(\mathrm{d}i/\mathrm{d}t)$.

The relation between $\bar{\theta}$ and $\bar{\phi}$ necessary to make the joule the unit of energy is the same for all formulations of the fundamental equations, for this is a mechanical unit. The required relation is easily found to be

$$\bar{\phi}\bar{\theta}^2 = (10)^7. \tag{A}$$

On the other hand the relation necessary to make the coulomb the unit of charge involves the parameter a and therefore is dependent on the particular formulation of the fundamental equations which is adopted. It is

$$\bar{\phi}^{1/2}\bar{\theta}^{3/2} = \frac{2.99796(10)^9}{\bar{a}}\left[\frac{a_p}{a}\right], \tag{B}$$

where $\bar{a}$ is the numerical part of the possibly dimensional constant a in c.g.s. units.

Now it would be most desirable if the physicist and the engineer were able to use the same set of symmetrical electromagnetic equations, the physicist employing c.g.s. units in these equations and the engineer practical units. We have seen that the equations most suitable to the physicist are either the Heaviside-Lorentz or the Gaussian equations. In either of these a is a dimensionless constant so that the ratio $[a_p/a]$ is unity and (A) and (B) admit unique solutions. Unfortunately, however, the units of mass and length in the practical system are not decimal multiples of the gram and the centimeter respectively, and the magnitudes of these units are as inconvenient as those in Maxwell's electromagnetic system.

If, however, a^2 is of the dimensions of a velocity, as in the Kennelly equations, relation (B) becomes

$$\bar{\phi}\bar{\theta}^2 = \left(\frac{2.99796(10)^9}{\bar{a}}\right)^2 \tag{B'}$$

which is consistent with (A) only if $\bar{a} = 2.99796(10)^{11/2}$. In this case we can determine *either* the unit of mass or the unit of length arbitrarily. If we take the meter as the unit of length the kilogram becomes the unit of mass. This choice of fundamental units gives us decimal multiples of the c.g.s. units of convenient magnitudes, and seems to be the one most favored by engineers. Another possibility is to retain the centimeter as the unit of length. Then the unit of mass is $(10)^7$ grams. Obviously the Kennelly equations in the form stated earlier cannot be used with practical units since the numerical part of a chosen there makes (B′) inconsistent with (A).

Since the inclusion of the eight internationally recognized practical units in our system of units fixes the constant a alone of the four constants appearing in the most general formulation of the fundamental equations, the criteria under discussion can be satisfied as well with an asymmetric as with a symmetric set of equations. In fact Campbell of the American Telephone and Telegraph Company has advocated the set of equations obtained by giving a the value cited and making $\beta = c/(4\pi a)$, $\gamma = 4\pi a$, $\delta = c/a$. Then

$$\nabla \cdot \mathbf{D} = \rho \quad (1), \qquad \nabla \cdot \mathbf{B} = 0 \quad (2),$$

$$\nabla \times \mathbf{E} = -\dot{\mathbf{B}} \quad (3), \qquad \nabla \times \mathbf{H} = \dot{\mathbf{D}} + \rho \mathbf{v} \quad (4),$$

$$\mathbf{D} = \frac{1}{4\pi a^2}\mathbf{E} + \mathbf{P} = \frac{\kappa}{4\pi a^2}\mathbf{E} \quad (5), \qquad \mathbf{B} = \frac{4\pi a^2}{c^2}\mathbf{H} + \mathbf{I} = \frac{4\pi a^2}{c^2}\mu\mathbf{H} \quad (6),$$

$$\mathbf{F} = \rho\{\mathbf{E} + \mathbf{v} \times \mathbf{B}\} \quad (7).$$

These equations, however, miss all the considerable advantages of symmetry, and therefore cannot be considered satisfactory.

A set of reasonably simple fundamental equations in symmetrical form which include the eight internationally recognized practical units and either the meter and kilogram or the centimeter and $(10)^7$ gram are obtained by making $\gamma = c/a$ in the general symmetrical formulation. They are

$$\nabla \cdot \mathbf{D} = \frac{4\pi a^2}{c}\rho \quad (1), \qquad \nabla \cdot \mathbf{B} = 0 \quad (2),$$

$$\nabla \times \mathbf{E} = -\dot{\mathbf{B}} \quad (3), \qquad \nabla \times \mathbf{H} = \dot{\mathbf{D}} + \frac{4\pi a^2}{c}\rho \mathbf{v} \quad (4),$$

$$\mathbf{D} = \frac{1}{c}\mathbf{E} + \frac{4\pi a^2}{c}\mathbf{P} = \frac{\kappa}{c}\mathbf{E} \quad (5), \qquad \mathbf{B} = \frac{1}{c}\mathbf{H} + \frac{4\pi a^2}{c}\mathbf{I} = \frac{\mu}{c}\mathbf{H} \quad (6),$$

$$\mathbf{F} = \rho\{\mathbf{E} + \mathbf{v} \times \mathbf{B}\} \quad (7).$$

These have the advantage that the coefficient $4\pi a^2/c$ is a *pure number,* having the value $4\pi(29.9796) = 376.735$. If we choose the meter and the kilogram as units of length and mass, the unit of **H** in this system has a value 1/29,980 gauss and the unit of **B** is 10,000 gauss.

The value of the parameter a used above was determined from the supposedly known value of the coulomb. However, we may satisfy the third requirement of the engineer by fixing arbitrarily the magnitude of the ohm, determining the ampere by the relation $Ri^2 = U/t$ or an equivalent, and then determining the coulomb by the defining equation $q = it$. Then the coefficient a would become divorced from the velocity of light c and each coefficient would have to be redetermined independently as methods of measurement became more precise.

To sum up, the symmetrical equations suggested for the engineer can be used with the meter, kilogram, joule, an arbitrarily fixed ohm and the remaining internationally recognized practical units defined in terms of these units. The coefficients involved are comparatively simple and the equations possess all the advantages of symmetry. On the other hand the physicist, and particularly the theoretical physicist, would prefer a set of equations with simpler coefficients. For his purposes the Heaviside-Lorentz equations provide the ideal formulation. As both sets are symmetrical, the transformations from one to the other are comparatively simple.

A DEFINITIVE SYSTEM OF UNITS

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ABSTRACT

Based on the original metric system there are many diverse systems of units for electricity and magnetism in use today. This multiplicity is the cause of much wasted effort in industry and science. The present paper offers a plan to end the confusion by the adoption of a single, preferred system of metrical units. This proposed "definitive system" is formed by sifting out and linking together the most familiar mechanical, electric and magnetic units, as shown by counts of the actual occurrences of unit names in current engineering and scientific periodicals. The definitive system of units is based upon the meter, the kilogram, the second and the ohm. It was first suggested in 1901 by Professor G. Giorgi. The defining equations have long been in use in the Heaviside rational electromagnetic system. The definitive system makes possible complete uniformity in the units of commerce, industry and science. There would be but one set of units and but one set of equations for universal use. It is believed that no possible plan will accomplish as much of advantage to all concerned with so little inconvenience as the plan here proposed. Since the International Bureau of Weights and Measures is soon to add the comparison of electric standards to its custody of metric standards, this presents a unique opportunity for initiating the use of the definitive system. This paper recommends that the Bureau designate the definitive system as its preferred system of metrical units.

PURPOSE AND SCOPE

The purpose of this paper is to convince you that a single system of metrical units should be internationally recognized for preferred, but not compulsory, use in commerce, industry and science, in all their ramifications, everywhere. This proposed system must include the mechanical, electric and magnetic units which past experience has shown to be most useful. It must be complete and authoritative, the last word on the subject: for this reason this proposed system is referred to in this paper as the "definitive system."[1]

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[1] "Definitive system" was suggested by the recognized use of "definitive edition" for the "final authoritative text of the complete works of an author." For a growing subject like physics, as for an active author, the use of "final" and "complete" may require toning down. Out of the present multiplicity of

It is timely that this logical, comprehensive attempt be made to set the metrical house in order.[2] The International Bureau of Weights and Measures is soon to add the comparison of electric and photometric standards to its custody of metric standards. The Bureau is very properly taking adequate time to determine precisely with what electric and photometric units it should start; it is not proposing merely to carry on with the units which are now in most general use. The Bureau is determined to secure the highest degree of both uniformity and precision. This conforms to the Metric Convention of 1875 which began by stating that the high contracting parties "desiring international uniformity and precision in standards of weight and measure, have resolved to conclude a convention to this effect." This calls for an objective appraisal of the essential usefulness of the meter and of all units based on the meter. No such study has ever been made, apparently, by any of the numerous committees or congresses of the past. New units, new names and new systems have been added to the metrical hierarchy, from time to time, but complete uniformity and the discarding of superfluous units have been neglected. Even the possibility of employing a single system of units for all purposes, everywhere, has seldom been mentioned.

The 1893 International Congress, in Chicago, will illustrate the essential divergences in point of view between past discussions and the one which I am submitting to you. First, I believe that commerce and industry should have a complete, coherent system of named units, built up around sixteen of those listed under the heading "Practical Units" in the table appended to the Report of the 1893 Congress. But the practical units adopted in 1893 included fifteen named non-coherent miscellaneous units, with no names for the remaining thirteen quantities covered by the table. Evidently, in 1893, industry had not advanced to a point where it realized the desirability of a complete, coherent system of named units. Second, I believe that science should use the same system of units as commerce and industry so as to facilitate communication between these great

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systems of units, however, one choice of units may well supersede the others in so far as our epoch is concerned and justify the application of "definitive" as "having the character of finality as a product; determinant, definite, fixed and final." I have been told that "definitive system" is forbidding and does not suggest scientific recognition of the popular usage in units. "Popular system" might be forbidding to the scientist. "Definitive system" was introduced as a temporary identification tag for a system which presents unique claims for universal use. The system has much in common with the metric, "absolute-practical," international, Giorgi and Robertson systems, but differs from each of them in some respect.

[2] English units and all other units which are based on a unit of length other than the meter are excluded from the discussion and tables of this paper. This paper is not concerned with the question of substituting metric for English units.

human activities. In 1893, on the other hand, the cgsm[3] system was taken for granted as the perfect and perpetual basis for all units, and considered suitable for physicists but not for practical engineers. It was the special function of the Congress to define the practical electric units as distinct quantities. Third, I believe that a multiplicity of systems inevitably makes for confusion. The official recommendations of the 1893 Congress supply a well-known example of such confusion. They give alternative definitions for some of the electric units but it is not made plain just how these alternatives are to be employed. Combining them in all possible ways gives thirty-seven different systems of electric units. Even if the eight units are fixed in the order given and all six defining relations are used, there still remain four different systems of electric units which comply with the official recommendations. This also holds for the U. S. act of 1894 legalizing electric units.

The following discussion of the units required to meet the needs of the future shows conclusively, I believe, that some mechanical units should be retained and others discarded; that some electric and magnetic units should be retained and others discarded. The units retained constitute the definitive system. *It is an extremely simple system of familiar units.* The arguments for its adoption as the universal system by the International Bureau of Weights and Measures have far greater weight than has the sum of the arguments for the individual features of the system considered as isolated items to be merely absorbed into the present multiplicity of unit systems. For this reason, I earnestly bespeak your consideration of the definitive system as an organic whole for universal use.

THE PROPOSED DEFINITIVE SYSTEM OF UNITS

The choice of units for inclusion in the definitive system raises the practical question: What units have the best chance of coming into preferred use as the voluntary choice of commerce and industry, the shop and the market place? The answer which I submit is Table 1. All the mechanical and electric quantities covered by the U. S. acts of 1866 and 1894, and by the more recent French law and decree of 1919, are included in the first column; and four important magnetic quantities have been added. They may be regarded as electric units and have been assigned electric names.

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[3] For brevity, following the International Critical Tables, the abbreviations cgs, cgsm, and cgse are used for centimeter-gram-second, centimeter-gram-second-electromagnetic, and centimeter-gram-second-electrostatic, respectively. These systems of units would all become superfluous with the introduction of the definitive system.

It is to be understood that the definitive system includes all the flanking units obtained by multiplying listed definitive units by all positive and negative powers of ten. This enormously increases the convenience and adaptability of the system. The nomenclature should include a more extended series of prefixes for powers of a thousand than the one now in use. The list of derived physical units goes beyond Table 1, some of them being included in Table 7 (page 68), which is added for convenient reference rather than for detailed discussion in this paper.

TABLE 1

A SHORT TABLE OF DEFINITIVE AND ORPHAN UNITS FOR MECHANICAL, ELECTRIC AND MAGNETIC QUANTITIES

Quantity		Symbol and defining equation	Definitive unit name	Orphan unit names (various defining equations)
1	Length	L	Meter	Micron, angstrom
2	Area	$S = L_1L_2$	Square meter	Are, square centimeter
3	Volume	$V = LS$	Stere = cubic meter	Liter, cubic centimeter
4	Time	T	Second	. . . .
5	Power	P	Watt	Erg per second
6	Energy	$W = PT$	Joule	Erg, kilogrammeter
7	Force	$\boldsymbol{\mathfrak{F}} = WL^{-1}$	Joule per meter	Gram, dyne, sthène
8	Pressure	$\mathfrak{p} = WV^{-1}$	Joule per stere	Bar, pièze, barye, gram per cm^2
9	Mass	$M = \boldsymbol{\mathfrak{F}}\mathfrak{a}^{-1}$	K(ilogr)am	Gram, ton, carat
10	Density	$d = MV^{-1}$	K(ilogr)am per stere	Gram per cubic centimeter
11	Electricity	Q	Coulomb	
12	Electric current	$I = QT^{-1}$	Ampere	
13	Electric potential	$E = WQ^{-1}$	Volt	
14	Electric capacity	$C = QE^{-1}$	Farad	
15	Electric resistance	$R = EI^{-1}$	Ohm*	
16	Electric inductance	$\mathfrak{L} = RT$	Henry	
17	Magnetomotive force	$\mathfrak{F} = NI$	Ampere-turn	Gilbert, centimeter-gauss
18	Magnetic field	$\mathfrak{H} = \mathfrak{F}L^{-1}$	Ampere-turn per meter	Gauss, gamma, oersted
19	Magnetic flux	$\Phi = ETN^{-1}$	Volt-second per turn	Line, maxwell
20	Magnetic flux density	$\mathfrak{B} = \Phi S^{-1}$	Volt-second per turn per square meter	Gauss, line per square centimeter

$\mathfrak{a}$ = acceleration in meters per second per second.

* The definitive ohm is the shop and laboratory ohm as distinguished from an abstract ohm. Its present value may be taken as legalized in the United States. Its future value is subject to changes through legal enactments. The value of the ohm fixes the value of the coulomb, since defining equations 12, 13, and 15 give $Q^2 = WTR^{-1}$; hence all electric and magnetic units are determined.

Unit names appearing in Table 1 have been placed in two columns. It will be noted immediately that the names in one column are, on the whole, more familiar than the names in the other. Thus, the meter is more familiar than the micron or angstrom; the watt is more familiar than the erg per second. Everyone will agree which of the two columns of names might be more properly exalted to a preferred position. This does not mean that every unit name in this column would be the preferred choice if that quantity could be considered alone and not as part of a coherent system.

The column containing the less important group of names is headed " Orphan unit names " to indicate that these are not included in the family of definitive units. It is intended to make and maintain a clear-cut distinction between the units in the definitive system and all orphan units outside this system. It is not necessary for the success of the definitive system that these orphan unit names should forthwith become obsolete. Presumably, the angstrom, liter, cubic centimeter, gram, metric ton, carat, and some other orphan names, will long continue in special use.

It will be noted that Table 1 includes the meter and kilogram which are internationally accepted as the fundamental units of the metric system. It also includes the second, ohm and ampere, which are the internationally accepted fundamental units of the legalized electric system. *It is a remarkable and fortunate coincidence that the fundamental units of the metric and international electric systems happen to fit together, after small adjustments, into a single, coherent system, using the defining equations with which we are familiar.*

Every defining equation[4] in the second column of Table 1 (except $\Phi = ETN^{-1}$) is of the simplest form, being either $X = YZ$ or $Y = XZ^{-1}$. To secure such simple defining equations the meter, second, watt and coulomb were chosen as the four primary units.[5] This choice was dictated by the resulting simplicity in tying together, in thought, the entire group of twenty units. For another purpose another choice of four primary units might be preferable. Thus, the volt is so frequently used that it might often be desirable to substitute it for either the coulomb or the watt. A variety of choices used at different times will help us to get away from the notion that length, mass and time have altogether unique claims as fundamental units.

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[4] Each defining equation relates to some definite physical measurement. To complete the definition the measurement must be described in detail. The measurement may be so chosen as to lead to a standard of the unit itself or to the measured value of any quantity of the same kind in terms of the unit. The second type of definition appeals to me, since for most of us the standard for the unit is given and we are concerned only with using it in measurement. The defining equations are not supplemented by these details in this paper because the definitive system presents no novelty in this respect. Integral signs and other complications have been excluded from the defining equations by a suitable choice of the physical measurements. Each defining equation implies an abstract unit, but the choice of defining equations in this table was not made to show which may best be regarded as abstract units.

[5] The use, in Table 1, of the watt and coulomb as primary units has been criticized because the watt and coulomb cannot now be preserved as standards with the precision of the kilogram and ohm. The kilogram is an excellent primary unit for bureaus of standards because of its permanence, accuracy in use, availability and convenience, but it does not connect well with electric units. The

Table 1 includes all eight electric units legalized in the United States. Commerce and industry do not need a law which presents either a scientific discussion of units or instructions for the establishment and maintenance of precision standards. All that is really needed seems to be, first, the assurance that there is a responsible authority for maintaining uniformity and precision in the standards for all units and, second, simple explanations of these units and standards which will enable commerce and industry to determine when they should turn to this authority for assistance in connection with their measurements. Changes in detail from the 1894 law would include the presentation of the joule and watt as mechanical rather than electric units and the presentation of definitive units as a self-contained universal system without any dependence upon the cgs, cgsm or other outside units. The cgs and cgsm units appear four times in the 1894 law. Magnetic units should be legalized as well as electric and mechanical units.

The one-syllable unit names, stere, watt, joule, volt, ohm, and the two-syllable names, meter, second, coulomb, ampere, farad, henry, of Table 1, are all excellent and it is extremely fortunate that one coherent system can include all of this group of unit names. The compound names derived from these eleven names are also convenient, as is evident from those listed in Table 1 and the longer list of Table 7. This leaves but one quantity having a unit name which is in direct conflict with the principles of nomenclature. I refer to the kilogram. Familiarity cannot justify the continued general use, by reasonable people, of a decimal prefix in the name for this fundamental unit. A possible remedy would be a contraction of kilogram to " kam " as indicated by the parentheses in Table 1; in this way Robertson derived " kram," in 1904; there are plenty of alternatives from which to choose. New names for both the force unit and the mass unit would aid clear thinking and eliminate the confusion which has

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watt makes a better connection, since it gives simpler defining equations with no fractional exponents. We are at liberty to choose the primary units to suit our convenience. For illustrations of the advantages of different choices for fundamental quantities see J. H. Dellinger, International System of Electric and Magnetic Units, *Bureau of Standards Scientific Paper* No. 292 (1916). From defining equations 6, 7, 9 and the equation $a = LT^{-2}$ for acceleration, we derive $P = ML^2T^{-3}$ which gives the watt in terms of the kilogram, meter and second.

resulted from the dual use of the name kilogram to designate sometimes a mass and sometimes the force of gravity. But I am not advocating specific names for these or any other units in this paper.

Table 1 is impressive because of its simplicity and the number of popular units which are included as definitive units. It should be stressed that the main change required by the universal use of the proposed system is the discarding of units which have not become popular but have been a source of confusion and annoyance. The definitive system means continuing the use of familiar units. It does not mean a transition period of difficulties, but a period of progressive simplification due to the discarding of superfluous units. *I am asking scientific recognition of the popular usage in units.*

EXTENSIVE COUNTS SHOW PREDOMINANT USE TODAY OF DEFINITIVE UNITS

I have had counts made of the metrical unit names occurring on a total of about 10,500 pages of the twelve periodicals listed in Table 2. In these counts every occurrence of every unit name has been included, the criterion being that of the proofreader. The count disclosed total occurrences

TABLE 2

COUNTS OF METRICAL UNITS IN TWELVE PERIODICAL PUBLICATIONS—LISTED BY THE PUBLICATION

	Periodical	Total count	Definitive units using		Other metrical units (per cent)
			Definitive names (per cent)	Other names (per cent)	
1	*Trans. Am. Inst. Elec. Eng.*, Second Quarter, 1932	2480	95.3	2.8	1.9
2	*Proc. Inst. Radio Eng.*, 1932	8475	98.5	1.3	0.2
3	*Trans. Am. Soc. Mech. Eng.*, First Quarter, 1926	356	96.6	3.4	0.0
4	*Trans. Am. Soc. Civil Eng.*, First Quarter, 1931	471	99.2	0.8	0.0
5	*Trans. Am. Inst. Min. Eng.*, Iron and Steel, 1930	267	74.5	22.5	3.0
6	*Trans. Am. Inst. Min. Eng.*, Geophys., 1932	653	65.5	25.6	8.9
7	*Terr. Mag. & Atmos. Elec.*, 1931	956	53.8	7.1	39.1
8	*Bell System Tech. J.*, 1932	1504	84.4	12.9	2.7
9	*Phil. Mag.*, Jan.-June, 1932	2726	76.1	19.3	4.6
10	*Phys. Rev.*, July-Dec., 1932	5428	59.5	36.6	3.9
11	*J. Am. Chem. Soc.*, Oct.-Dec., 1932	4282	28.9	71.1	0.0
12	*Monthly Notices, Royal Astron. Soc.*, Nov., 1930–Oct., 1931	944	68.2	30.5	1.3
	Grand total	28542	74.0	22.9	3.1

of 28,542 metrical unit names in a text of about five million words. Of this total, 74 per cent of all metrical unit names were definitive unit names. The percentages for individual periodicals range from 99 down to 29.

The counts indicate an actual use today of definitive unit names of about 98 per cent by the civil, radio, mechanical and electrical engineers. The actual counts were about 99, 98, 97 and 95 per cent for the transactions of these four great American engineering societies, respectively. Definitive units are thus largely the metrical units of engineering. This is so because the units chosen for the definitive system were, as far as possible, the metrical units used by engineers and industry. The counts indicate a use of definitive unit names by physicists of about 65 per cent, viz., 76 per cent in the *Philosophical Magazine* and 60 per cent in the *Physical Review.* The explanation of these lower counts and of the still lower counts for terrestrial magnetism and chemistry is to be found in the use of a few of the orphan units of Table 1. These will now be considered.

Table 3 summarizes the counts by unit names, ignoring decimal prefixes. The names volt and meter lead the list. They give 25 and 17 per cent of the total, respectively. Counts, all above one-half of one per cent of the total, occur for sixteen definitive unit names, including cycle (cycle per second), second, ampere, ohm, watt, farad, meter per second, henry, and volt per meter. The nine non-definitive unit names, gram, angstrom, cubic centimeter, centimeter^{-1}, micron, liter, square centimeter, gamma and gauss, also occur with frequencies of over one-half of one per cent each. If these nine non-definitive names were replaced by definitive names, the grand total count of definitive unit names would be raised 22.3 per cent, from 74 per cent to 96.3 per cent. This would leave only 3.7 per cent of the occurrences to cover all the remaining names in Table 3, including 24 cgs names, 23 cgsm names, 16 cgse names and 47 miscellaneous names. Uniformity, convenience and intelligibility would be served by discarding most of these non-definitive names in favor of definitive names. On the other hand, special names may be justified, temporarily at least, for special purposes. The number of such cases would be small compared with the number of non-definitive names in Table 3. Recognition of the admissibility of using a limited number of special names has been indicated by listing orphan unit names in the last column of Table 1.

The fact that no orphan unit names are of sufficient importance to be included as alternatives for the second, coulomb, ampere, volt, farad, ohm and henry, in Table 1, seems to show that when short names suitable for the shop and market place have been assigned officially at an early date,

TABLE 3

COUNTS OF METRICAL UNIT NAMES IN THE TWELVE PERIODICAL PUBLICATIONS OF TABLE 2 LISTED BY THE UNIT NAMES WITH DECIMAL PREFIXES IGNORED

Definitive units using 42 definitive names		Definitive units using 86 other names	
7037	volt	1914	gram
4737	meter	1175	angstrom
1951	cycle (f)	1117	cc (= milliliter)
1390	second	658	centimeter^{-1}
1141	ampere	469	micron
1053	ohm	221	liter
1043	watt	170	square centimeter
416	bel	110	cubic centimeter
415	cycle per second	84	volt per centimeter
396	farad	77	ohm-centimeter
316	meter per second	68	bar (= dyne/cm^2)
188	henry	37	erg
185	cycle (θ)	27	gram per cubic centimeter
177	volt-ampere	26	square millimeter
156	revolution	24	gram-centimeter^2
149	volt per meter	24	cgsm unit (γ)
100	number per second	23	dyne
56	turn	21	gram per square centimeter
40	radian	18	dyne per centimeter
34	coulomb	17	dyne per square centimeter
23	mho	16	ohm per cubic centimeter(ρ)
17	second^{-1}	15	x-unit
15	ohm-meter	14	gram per cc
14	(ohm per meter)-(square meter)	13	ampere per square centimeter
11	revolution per second	11	poise
11	ampere-turn	11	ohm (ρ)
9	joule	10	(erg per square centimeter) per second
8	hertz	10	cgsm unit (ρ)
6	square meter	9	square angstrom
5	ohm^{-1}	9	(erg per square millimeter) per second
3	ampere per volt	8	cgsm unit (υ)
2	cubic meter	7	gram per cubic meter
2	diopter	6	volt per kilometer
2	radian per second	5	cubic centimeter per second
2	meter per second per second	5	cgsm unit (Q)
2	coulomb per second	4	erg per second
1	cubic meter per second	4	watt per square centimeter
1	watt-second	4	cgsm unit ($\mathfrak{L}$)
1	meter-ohm	3	A (= 10^{24} cm)
1	ohm per (meter per square meter)	3	square kilometer
1	henry per meter	3	cubic millimeter
1	radian^{-1}	3	liter per second
		3	(erg per second) per square centimeter
21118 = 74.0%			

Grand total for all 162 metrical unit names = 28542 = 100%.

The symbols in parentheses identify the physical quantity by reference to Table 7 below.

Kilogram does not occur among the definitive names in the first column because of the decimal prefix; 87 occurrences of kilogram were counted; they are included in the total for the gram in the second column of the table, which is 1914.

TABLE 3—*Continued*

Definitive units using 86 other names (*continued*)	**Other metrical units 34 names**
3 erg per cubic centimeter	335 gamma
3 erg per square centimeter	189 gauss ($\mathbf{H}$)
3 bar (= megadyne/cm^2)	65 gram ($\mathbf{F}$) per square millimeter
3 ampere per square decimeter	59 gram ($\mathbf{F}$) per square centimeter
3 cgsm unit ($\mathbf{i}$)	38 oersted ($\mathfrak{H}$)
3 cgsm unit (R)	30 oersted ($\mathbf{H}$)
3 ohm per (centimeter per square centimeter)	29 cgsm unit ($\mathbf{H}$)
3 mho per centimeter	21 cgse unit (γ)
3 line per square centimeter	18 cgse unit (Q)
3 gauss ($\mathbf{B}$)	12 centimeter-gauss
2 cubic decimeter	10 gram ($\mathbf{F}$)
2 metric atmosphere (= megadyne/cm^2)	9 cgse unit (υ)
2 ton (metric)	8 lyne (Heaviside unit, Φ)
2 gram per liter	7 cgse unit ($\mathbf{Q}$)
2 gram per second	7 cgse unit (I)
2 cgs unit ($\mathbf{J}$)	6 cgse unit (Q) per cubic meter
2 cgsm unit (E)	6 cgse unit (C)
2 ohm-meter-meter (ρ)	5 cgse unit (E) per centimeter
2 ohm per centimeter (ρ)	5 centimeter (C)
2 maxwell	5 cgse unit (ρ)
2 line	5 gilbert per centimeter
1 cubic micron	4 cgse unit (δ)
1 cubic kilometer	4 cgse unit ($\mathbf{i}$)
1 millimeter^{-1}	3 cgse unit (E)
1 cgs unit ($\mathbf{v}$)	3 cgse unit (G)
1 erg-second	2 cgse unit (Q) per cc
1 dyne-centimeter	2 unit pole per square centimeter
1 cgs unit ($\mathbf{t}$)	1 cgse unit ($\mathbf{E}$)
1 cgs unit (s)	1 rational cgse unit (κ)
1 gram per milliliter	1 rational cgse unit (γ)
1 cgs unit (d)	1 cgsm unit (β)
1 cgsm unit (σ)	1 cgse unit ($\mathbf{q}$)
1 cgsm unit (I)	1 cgsm unit ($\mathfrak{F}$)
1 absolute unit (I)	1 cgs gaussian unit ($\mathbf{H}$)
1 absolute unit (E)	
1 volt per micron	
1 ohm per cubic meter (ρ)	
1 ohm-(square centimeter) per centimeter	
1 (ohm per centimeter)-(square centimeter)	
1 mho per cubic centimeter (γ)	
1 (ohm-centimeter)$^{-1}$	
1 practical unit (γ)	
1 practical unit ($\mathfrak{L}$)	
6530 = 22.9%	894 = 3.1%

Much additional information is to be obtained from our original work-sheets for the counts, which will be loaned on request.

everyone is likely to find it advantageous to adhere to these names. This holds even when the unit always requires a decimal prefix for everyday use, as is strikingly shown by the microfarad and the micromicrofarad.

Table 3 confirms the well-known fact that the six legalized electric units, with the following definitive names, are used almost to the exclusion of the cgs units for the same physical quantities. The corresponding counts derived from Table 3 are:

Volt	7037	6
Ampere	1141	9
Ohm	1053	3
Farad	396	11
Henry	188	5
Coulomb	34	23
Total	9849	57

Thus, these six definitive names occur about 170 times for one occurrence of a cgs unit name.

The volt is used with amazing uniformity. The counts were 7037 for the volt and 6 for all competing units. *The volt is preferred over alternative units 1000 to 1.* This is practically equivalent to saying that the volt is the only unit of electric potential which is in use today by physicists and engineers. It follows that there can be at present no consistent use of the cgsm and cgse units. Both systems of units have been largely discarded. There can be nothing in the assertion which is sometimes heard, that the physicist will never give up the cgs systems. The vote that "the C.G.S. system of units is suitable for the physicist" at the S.U.N. meeting in Paris, July, 1932 [A. E. Kennelly, Conference of the Symbols, Units and Nomenclature (S.U.N.) Commission, *Proc. Nat. Acad. Sci.* 19: 144-149 (1933)] is not supported by the units which physicists actually find it suitable to use in their published papers.

Finally, this count has also contributed Table 4, which shows that about 41 per cent of the unit name occurrences include decimal prefixes. Prefix "centi-" leads the list with a total of 4836, all but three of which were for the "centimeter," which has been exalted in the cgs systems out of line with other flanking units for the meter. There are no occurrences of centimilli-, decimilli-, deka-, hekto-, myria- and hektokilo-, all of which are legalized in France. Thus the decimal prefixes which stand for positive and negative powers of 1000 are used in preference to the other prefixes. It seems desirable to extend the series of two-syllable prefixes, micro-, milli-, kilo-, mega-, in both directions by powers of 1000, so as to cover more adequately and conveniently the range of magnitudes which occur in modern physics and astronomy. The practical success of the metric decimal prefixes in meeting the widely varied needs of commerce, industry and science is most remarkable. Now that the genius of this nomenclature is appreciated, in a way not possible when the metric system was introduced, strict rules of nomenclature should be observed restricting the decimal prefixes to this one important function.

TABLE 4

Counts of Decimal Prefixes in the Twelve Periodical Publications of Table 2

Prefix	Total	
Micromicro-	182	
Millimicro-	0	
Micro-	576	
Centimilli-	0	
Decimilli-	0	
Milli-	2488	
Centi-	4836	(4833 centimeters included)
Deci-	469	(416 decibels included)
Deka-	0	
Hekto-	0	
Kilo-	2937	
Myria-	0	
Hektokilo-	0	
Mega-	326	
Total	11814	= 41.4% of total count, 28542

ADVANTAGES OF THE DEFINITIVE UNIT MAGNITUDES

The second of time is a unit in wide everyday use and an appreciation of both its magnitude and nature underlies our civilization. It is not so short an interval as to be difficult to comprehend nor so long as to require protracted mental concentration throughout its duration. It illustrates the fact that everyday familiarity is a desirable characteristic of each unit, just as far as that is feasible. Most of the derived units are not in everyday use, many are somewhat intangible, and many of the magnitudes have by common consent been dictated by the desirability of using certain simple defining equations to bind the units into a coherent system. However, three arbitrary units in addition to the second enable us to secure at least three more convenient magnitudes.

For metric countries the magnitudes of the meter and the kilogram satisfy every condition of familiarity. The meter can be precisely duplicated in different countries and can be visualized more readily than the angstrom and millimeter, on the one hand, or the kilometer and megameter, on the other hand. The kilogram is more familiar in the market place than either the gram or the metric ton.

Various writers have pointed out that the length of the centimeter and the mass of ten metric tons conform with the watt and second, and have advocated that these units be used for length and mass in place of the meter and kilogram, because they consider the centimeter more convenient and familiar than the meter for many scientific and electrical engineering purposes. They seem to forget that the number of persons who are now familiar with the use of the meter and kilogram is very large; in fact, in all metric countries everyone buys something by length or weight. The familiarity and stability of the units of length and mass for commerce and industry are therefore of first importance. This dictates retaining the meter and the kilogram. The scientist and the electrical engineer will gain far more by conforming to these two fundamental units of commerce and industry than by using their own special ones, such as the centimeter and gram of the cgs system or the centimeter and ten metric tons of a more recent proposal.

The fourth unit must be taken outside the mechanical domain and is more elusive. The volt is the unit occurring most frequently in our counts; its approximate magnitude has been made familiar by the dry cell. There is no better magnitude.

The derived units cannot all be of convenient size for everyday use. However, the mechanical units of Table 1 are all good. The use of stere for cord wood does not interfere in the least with its use for the precision laboratory or for astronomy. The joule per meter equals the weight of 0.1020 kilogram which is a force in the everyday range. Its importance justifies an effort to provide a distinctive name having no more than two syllables. The joule per stere is a pressure equal to the weight of 0.1020 kilogram per square meter. The list of four orphan units for pressure suggests that this merits a name of its own. The kilo- prefix would give a convenient unit for atmospheric pressure.

All electric unit magnitudes, except the coulomb, are familiar to the radio amateur. The acceptance of microfarad in radio is evidence that the micro- and mega- prefixes will make the magnitudes of all four magnetic units in Table 1 generally acceptable.

ADVANTAGES OF THE AMPERE-TURN

By using the ampere-turn every defining equation in Tables 1 and 7 is factor-free. This is a most desirable uniformity. With this convention, the magnetomotive force linked with an electric circuit of one turn has the same numerical value as the current. Thus, the electric and the magnetic sides of this basic phenomenon are both expressed by the same numerical value. This simplifies greatly the comprehension of the electromagnetic phenomenon. To encumber one part of this two-sided phenomenon with the 4π of the cgsm system introduces an artificial, annoying and masking numeric. There is no reason for including the 4π in the definitive system.

The ampere-turn has long been used; it is most easily understood by commerce and industry. The ampere-turn denotes the magnetomotive force associated with the ampere; it connotes the flow of an ampere of electricity. For the ampere the denotation and connotation are interchanged. Both the ampere and the ampere-turn imply the same total phenomenon and assign the same numerical value to any specific case of the phenomenon. This is as it should be. The ampere-turn conforms to the modern concept that magnetic phenomena do not afford an independent connection between ether and matter, but merely a different aspect of the electric current phenomenon.

The electric current and magnetic field were, 100 years ago, two distinct phenomena; there was nothing to indicate that they were not quite independent; there was no intimation that they were as closely connected as the two sides of a coin. It is, therefore, not surprising that the first early units for electricity and magnetism did not assign the same numerical value to the ampere and the magnetomotive force associated with one ampere-turn. But it is surprising that this discrepancy between terminology and fact should have continued for decades after it had been definitely established that the ampere and ampere-turn are the obverse and reverse sides of the same tremendously important electromagnetic phenomenon. It would be even more astonishing if the illogical use, with the ampere, of any other unit of magnetomotive force than the ampere-turn should long continue.

It is now easy to see why the votes, reported during the last few years in the technical and scientific publications, on the practical unit of magnetomotive force have been about equally divided between the ampere-turn and the $(10/4\pi)$ ampere-turn. Votes for the ampere-turn were votes for consistency with the ampere. Votes for the $(10/4\pi)$ ampere-turn were votes for consistency with the cgsm units. The voters were trying to serve two masters—one master being the shop system user and the other the cgsm system user. Now that we are merging these two masters, the question becomes: "Assuming that we are to have one preferred, universal system of units, including the meter, second, watt and ampere, should the preferred unit of magnetomotive force be the ampere-turn?" The obvious answer is "Yes."

Both the ampere-turn and volt-second per turn have always been one and the same for everyone. They are thus well suited to replace the cgsm magnetic units which have gone under conflicting names with much resulting confusion during the past thirty or forty years. The ampere-turn would doubtless have been universally adopted nearly forty years ago if it had not been for the traditional prestige of the cgsm system.

With the inclusion of the ampere-turn in the definitive system, all defining equations become identically the well-known convenient defining equations of the Heaviside rational electromagnetic system of units.

THE DEFINITIVE OHM AND THE SHOP OHM

The definitive ohm, volt, ampere, henry and farad are to be the electric units actually used for shop and laboratory standards with such adjustments as may be needed to bring these units into coherence with the mechanical units. Small adjustments are necessary because the mechanical watt is about 260 parts in a million smaller than the electric watt of the present legalized international system of electric units. These adjustments may be made in different ways. One of the simplest is to retain the present shop ohm, that is, the international ohm, and to make adjustments in the shop ampere and volt. Shop units, adjusted in this manner, could be taken as the definitive units, for the present. The necessary differences between the shop electric units and the definitive electric units are, however, not of importance for the great bulk of experimental work because they fall within the tolerances for even precision commercial apparatus. This comparison is shown by Table 5.

Thus, while precision commercial apparatus has resistances adjusted to a tolerance of 100 parts in a million, tolerances of 1000 or more parts in a million are permitted for wattmeters, ammeters, voltmeters, condensers and inductances. These tolerances, shown in the third column of Table 5, are much larger than the adjustments, shown in the fourth column. Thus, present shop electric apparatus may be used for all ordinary purposes with the definitive system without readjustment or calibration. It is only for work with potentiometers and other methods of high precision that recalibration will be required.

When the International Bureau of Weights and Measures assumes jurisdiction over the electric units, in addition to its present jurisdiction over metric units, changes will be made in our legalized electric units which will mean corresponding changes in our shop and laboratory electric units. The definitive system must follow and make the same changes in its units. If the International Bureau substitutes the "absolute-practical" units[6] for the international units, the adjustments in the units will be approximately as shown by the fifth column of Table 5 under the heading: "Absolute-practical" ohm. This will call for a decrease of about 460 parts in a million in the value of the ohm. This adjustment, which is roughly five times the tolerance for the ohm, is the only one which exceeds the listed tolerances. Thus, even precision commercial apparatus will not require readjustment except for precision resistances. Of course, there would be recalibration of standard cadmium cells and other equipment for use with precision potentiometer methods.

TABLE 5

TOLERANCES FOR PRECISION COMMERCIAL APPARATUS AND UNIT CHANGES

Unit	Range	Parts in a million			Reference for tolerance
		Tolerance	Adjustment of international unit for use with		
			International ohm	"Absolute-practical" ohm	
Millimeter......	25–500	2	0	0	Ford: Johansson Gage Blocks, p. 3, 32
Watt (electric)..	75–6000	1000	−260	−260	Weston 1931 Catalog, p. 48
Gram..........	100–1000	5	0	0	Eimer and Amend Cat. BCM 1927, p. 61
Ampere........	0.15–1500	1000	−130	+100*	Weston, *ibid.*, p. 12, 48, 93
Volt...........	0.1–300	1000	−130	−360	Weston, *ibid.*, p. 12, 48
Microfarad.....	0.0001–1	2500	0	+460	Leeds & Northrup, 1927 Cat. No. 10, p. 5, 8
Ohm...........	1–10000	100	0	−460*	Leeds & Northrup, 1927 Cat. No. 40, p. 5, 22
Millihenry......	1–1000	2500	0	−460	Leeds & Northrup, 1927 Cat. No. 10, p. 13

* All tabulated unit increases are based on these two recent experimental results for the "absolute-practical" ohm and "absolute-practical" ampere in terms of the U. S. Bureau of Standards international standards.

Possibly a tolerance of one part in a million could be cited for timekeepers but I have not found a reference which seemed to parallel the tabulated entries for other quantities.

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[6] To be explicit "absolute-practical" is used in this paper to designate the units which are sometimes referred to as "absolute" and at other times as "practical." The term "absolute" may, by an unfortunate precedent, be applied to any system of units which employs units of length, mass and time as fundamental quantities; to designate a unit simply as an absolute unit is ambiguous. To designate a system as practical is also ambiguous because the so-called "practical" units, which are decimal multiples of the cgsm units, are abstract, impractical units and are thus not the units which are realized in our practical shop units. The definitive system is both "absolute" and "practical" but it seems better to avoid establishing the use of either term in this connection.

Ultimately, the electric units will present an international uniformity [7] and precision which will presumably compare favorably with those of the metric units. This stage can be reached, however, only through a transition period which is required to bring the electric units into conformity both internationally and with the mechanical watt. The confusion accompanying this transition would be minimized by the adoption of the definitive system as the single, preferred system.

COMPLETE PHYSICAL EQUATIONS FOR THE DEFINITIVE SYSTEM

In any system, for which units are all derived by factor-free defining equations from arbitrary fundamental units, no unit stands in any simple numerical relation to any universal constant of nature, such as the inductivity, the capacitivity and the characteristic impedance of free space, or the velocity of light. The universal constants are then not simple numbers; their values are experimentally determined and thus subject to change as precision improves; it is simpler to represent them by letter symbols in the various equations based upon such a system of units. These equations are then physically complete equations, and each one is physically and not merely numerically significant. This is an important advantage [8] which goes naturally with the definitive system where all defining equations are factor-free, as is shown by Table 7. The four fundamental units are all arbitrary; there is a prototype for the meter and another for the kilogram, the rotating earth is a prototype clock for the second; the present definitive ohm taken as the international ohm differs by an accidental amount from the abstract

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[7] International uniformity in electric units could be realized with smaller adjustments than are required by the change to the "absolute-practical" ohm. The mean of the world's present working ohm standards seems to be only about 20 parts in a million greater than the Bureau of Standards international ohm standard. If this value of the ohm were adopted by the International Bureau, the United States adjustments in the electric units would differ by about 20 or less parts in a million from the adjustments given for use with the international ohm in Table 5. All adjustments would then fall within the listed tolerances. Considering the definitive system only this plan of adjustment has much in its favor; it would tend to conserve the world's precision commercial electric standards.

[8] A recognized need of complete equations is the recent proposal to use μ_0 and K_0 in formulas relating to free space where the permeability and dielectric constant are each unity. Using letters to give physical meaning to equations will make a stronger appeal if the numerical value attached to the latter is not precisely unity or other familiar number, such as 4π. The velocity of light which is about 680 parts in a million less than 300 megameters per second may serve to illustrate this point.

" absolute-practical " ohm. None of the four units bears a simple numerical relation to any universal constant of nature. The " new international ohm " to be promulgated by the International Bureau of Weights and Measures will, in the final analysis, also be arbitrary. It is to be established in essentially the same way as the 1893 international ohm. Its value is to be assigned with a precision of one part in a million or better whereas the absolute measurements are not expected to give a precision of even ten parts in a million.

If we consider the fact that the ohm of the shop and laboratory is now and always will be an arbitrary unit in the last analysis, we are encouraged to use complete equations with the definitive system. To illustrate some of their advantages the following table is presented:

TABLE 6

FORMULAS FOR RIGHT PRISMS, POWER DENSITY AND CURL

Quantity*	In definitive units		In cgs electromagnetic units	
	Any medium	Free space	Any medium	Free space
Right prisms				
Capacity C	$\kappa \frac{S}{L}$	$\kappa \frac{S}{L}$	$\frac{K}{4\pi c^2} \frac{S}{L}$	$\frac{1}{4\pi c^2} \frac{S}{L}$
Conductance G	$\gamma \frac{S}{L}$	0	$\gamma \frac{S}{L}$	0
Inductance (for one turn) $\mathfrak{L}$	$\chi \frac{S}{L}$	$\chi \frac{S}{L}$	$4\pi\mu \frac{S}{L}$	$4\pi \frac{S}{L}$
Permeance $\mathfrak{P}$	$\nu \frac{S}{L}$	$\nu \frac{S}{L}$	$\mu \frac{S}{L}$	$\frac{S}{L}$
Power density (diverging)				
Dissipative	$-\gamma \mathbf{E}^2$	0	$-\gamma \mathbf{E}^2$	0
Electric	$-\kappa \mathbf{E}\cdot\dot{\mathbf{E}}$	$-\kappa \mathbf{E}\cdot\dot{\mathbf{E}}$	$-\frac{K}{4\pi c^2} \mathbf{E}\cdot\dot{\mathbf{E}}$	$-\frac{1}{4\pi c^2} \mathbf{E}\cdot\dot{\mathbf{E}}$
Magnetic	$-\nu \mathbf{H}\cdot\dot{\mathbf{H}}$	$-\nu \mathbf{H}\cdot\dot{\mathbf{H}}$	$-\frac{\mu}{4\pi} \mathbf{H}\cdot\dot{\mathbf{H}}$	$-\frac{1}{4\pi} \mathbf{H}\cdot\dot{\mathbf{H}}$
Total	$\operatorname{div} (\mathbf{E} \times \mathbf{H})$	$\operatorname{div} (\mathbf{E} \times \mathbf{H})$	$\frac{1}{4\pi} \operatorname{div}(\mathbf{E} \times \mathbf{H})$	$\frac{1}{4\pi} \operatorname{div}(\mathbf{E} \times \mathbf{H})$
Curl				
curl $\mathbf{H}$	$\gamma\mathbf{E} + \kappa\dot{\mathbf{E}}$	$\kappa \dot{\mathbf{E}}$	$4\pi\gamma\mathbf{E} + \frac{K}{c^2}\dot{\mathbf{E}}$	$\frac{1}{c^2}\dot{\mathbf{E}}$
−curl $\mathbf{E}$	$\nu\dot{\mathbf{H}}$	$\nu \dot{\mathbf{H}}$	$\mu \dot{\mathbf{H}}$	$\dot{\mathbf{H}}$

* Quantities and symbols are used as listed in Table 7. The symbols K and μ are respectively the dielectric constant and the permeability of the cgse and cgsm systems. They are pure numerics; the relative capacitivity and the relative specific permeance of the medium with respect to free space.

Table 6 shows, in parallel columns, a number of the simpler electromagnetic formulas in definitive and cgsm units. The formulas for right prisms come first. They are in constant use in the shop, laboratory and study. Consider first the four formulas in definitive units in "Any medium." Each formula involves a coefficient, κ, γ, χ, or ν, multiplied into the cross-section of the prism, divided by its length. The coefficients stand for the capacitivity, conductivity, inductivity and specific permeance, respectively, all of which are experimental constants in the definitive system. There is thus complete uniformity among these four formulas, which is as it should be. For free space, experiment shows that the conductance vanishes; the remaining three formulas are uniform, as is shown by the next column for "Free space." All of the formulas in definitive units are complete, which means that any of the four-fold infinite number of systems of definitive model units may be used with each formula.

The corresponding formulas using cgsm units do not present the same uniformity. A 4π appears for capacity in the denominator, for inductance in the numerator, while for conductance and permeance it does not appear at all. The formulas are not physically complete formulas; they are inferior to the definitive formulas.

The remainder of Table 6, for power density and for curl, presents the same contrast: uniformity, simplicity and physical completeness for the proposed formulas in definitive units; on the other hand, non-uniformity, greater length and physical incompleteness for the formulas in cgsm units.[10]

ADVANTAGES OF THE DEFINITIVE SYSTEM USED UNIVERSALLY

Complete uniformity in units will be attained only when a single system is in use everywhere, in the shop, market place, test room, laboratory and study. With decimal prefixes, and some small latitude in the use of orphan units, this is not a visionary ideal, even for the immediate future. Our counts show that within 3 per cent it is already achieved for the seven unit names, second, ampere, volt, farad, ohm, henry and meter per second. There can be no doubt but that this list would be extended rapidly if the possibility and advantages of uniformity were clearly set forth to industrial and scientific workers. We are already three-quarters of the way towards this goal if we agree to measure our position by the Table 2 percentages for definitive name occurrences in current technical and scientific publications. *We already have uniformity in the use of the volt, except for one case in a thousand.*

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[10] Formulas and equations are not discussed at length in this paper because the definitive units lead to the same analytical expressions as the Heaviside rational electromagnetic units. This is so because the latter system is a model system conforming to the last column of Table 7. In particular there is no discussion of inverse-square laws, none of which plays any part in the definition of definitive units. Thus, the three inverse-square laws for masses, electric charges and magnetic poles are all uniformly neglected in defining the units of the definitive system.

The universal use of the definitive system would tie all measurements to the most familiar units. This would aid in making all measurements comprehensible both in magnitude and nature. It would eliminate the necessity for translating numerical results and formulas from one set of units to another. It would aid in the communication of ideas between workers in different fields, between the theoretical and industrial workers in each field, and between groups in different nations. The definitive system is better adapted to serve as a universal solvent than any cgs system. Transition inconveniences would be negligible compared with the future gain from uniformity.

Many definitive units are shown in Table 7. The last column, for model units, shows the values in definitive units of any system of units which satisfies the same defining equations as the definitive units and thus leads to identically the same formulas and equations generally. Model systems for work in atomic physics, radio and astronomy may be advantageous. Multiples of units could be chosen having the same order of magnitude as the corresponding quantities presented by the particular phenomenon. The Heaviside rational electromagnetic system is a model system but it does not seem to be one which will be useful after the definitive system is in use.

The values of units in five of the historical metrical systems are given in Table 8. These tabulated values may be used as conversion factors for translating either numerical results or formulas into the definitive system. The existence of such a table demonstrates the adequacy of the definitive system for universal use and shows that a working familiarity with definitive units is all that either the industrial or theoretical worker really needs. He can rely on the table for translating any other units which he encounters in the literature.

Table 8 must be used as a continuation of Table 7, but it has been presented as a separate table to emphasize the fact that it is not involved as a part of the definitive system. After we have advanced to a point where there is but one system of units in general use, Table 8 will be used only in reading the older literature. It will then be relegated to reference books. The variety and complexity of the conversion factors appearing in this table are a plain demonstration of the inconvenience of the present multiplicity of metrical units. This table, with its terrible array of conversion factors, should aid in bringing about the discarding of superfluous systems and the use of one universal system of units.

With the recognition of the definitive system as the preferred one, new domains in industry and science would be developed from the start

TABLE 7
DEFINITIVE AND MODEL UNITS

	Quantity	Symbol and defining equation for definitive units	Definitive unit name	Value* in definitive units of model unit
1	Length	L	Meter	L
2	Reciprocal length	$\Upsilon = L^{-1}$	Diopter = meter^{-1}	L^{-1}
3	Area	$S = L_1L_2$	Square meter	L^2
4	Volume	$V = SL$	Stere = cubic meter	L^3
5	Time	T	Second	T
6	Damping constant	$k = T^{-1}$	Second^{-1}	T^{-1}
7	Frequency	$f = NT^{-1}$	Cycle, number per second	T^{-1}
8	Angular frequency	$\omega = \theta T^{-1}$	Radian per second	T^{-1}
9	Velocity	$\mathbf{v} = LT^{-1}$	Meter per second	LT^{-1}
10	Flow	$\mathbf{V} = VT^{-1}$	Stere per second	L^3T^{-1}
11	Acceleration	$\mathbf{a} = \mathbf{v}T^{-1}$	Meter per second per second	LT^{-2}
12	Power	P	Watt	P
13	Power flux	$\mathbf{S} = PS^{-1}$	Watt per square meter	PL^{-2}
14	Power density	$p = PV^{-1}$	Watt per stere	PL^{-3}
15	Energy	$W = PT$	Joule	PT
16	Energy flux	$\mathbf{U} = WS^{-1}$	Joule per square meter	PTL^{-2}
17	Energy density	$w = WV^{-1}$	Joule per stere	PTL^{-3}
18	Action	$\mathfrak{A} = WT$	Joule-second	PT^2
19	Volume elasticity	$\mathfrak{E} = VW^{-1}$	Stere per joule	$L^3P^{-1}T^{-1}$
20	Rigidity	$\mathbf{R} = WV^{-1}$	Joule per stere	PTL^{-3}
21	Viscosity	$s = \mathbf{U}\mathbf{v}^{-1}$	(Joule per square meter) per (meter per second)	PT^2L^{-3}
22	Fluidity	$r = \mathbf{v}\mathbf{U}^{-1}$	(Meter per second) per (joule per square meter)	$L^3P^{-1}T^{-2}$
23	Force	$\mathbf{F} = WL^{-1}$	Joule per meter	PTL^{-1}
24	Force per unit volume	$\mathbf{f} = \mathbf{F}V^{-1}$	(Joule per meter) per stere	PTL^{-4}
25	Torque	$\mathbf{t} = \mathbf{F}L$	(Joule per meter)-meter	PT
26	Surface tension	$U = \mathbf{F}L^{-1}$	(Joule per meter) per meter	PTL^{-2}
27	Pressure	$\mathbf{p} = WV^{-1}$	Joule per stere	PTL^{-3}
28	Mechanical compliance	$B_m = L\mathbf{F}^{-1}$	Meter per (joule per meter)	$L^2P^{-1}T^{-1}$
29	Acoustic compliance	$B_a = V\mathbf{p}^{-1}$	Stere per (joule per stere)	$L^6P^{-1}T^{-1}$
30	Mechanical impedance	$Z_m = \mathbf{F}\mathbf{v}^{-1}$	(Joule per meter) per (meter per second)	PT^2L^{-2}
31	Acoustic impedance	$Z_a = \mathbf{p}\mathbf{V}^{-1}$	(Joule per stere) per (stere per second)	PT^2L^{-6}
32	Mass	$M = \mathbf{F}\mathbf{a}^{-1}$	Kilogram	PT^3L^{-2}
33	Surface density	$u = MS^{-1}$	Kilogram per square meter	PT^3L^{-4}
34	Density	$d = MV^{-1}$	Kilogram per stere	PT^3L^{-5}
35	Precipitation	$b = MT^{-1}$	Kilogram per second	PT^2L^{-2}
36	[illegible]	[illegible]	[illegible] second	[illegible]

TABLE 8
CONVERSION FACTORS FOR HISTORICAL UNITS

	Value* in definitive units of				
	Cgs electro-magnetic unit	Cgs electro-static unit	Heaviside rational electro-magnetic unit	Lorentz rational Gaussian unit	MKS gravita-tional unit
1	10^{-2}	10^{-2}	10^{-2}	10^{-2}	1
2	10^{2}	10^{2}	10^{2}	10^{2}	1
3	10^{-4}	10^{-4}	10^{-4}	10^{-4}	1
4	10^{-6}	10^{-6}	10^{-6}	10^{-6}	1
5	1	1	1	1	1
6	1	1	1	1	1
7	1	1	1	1	1
8	1	1	1	1	1
9	10^{-2}	10^{-2}	10^{-2}	10^{-2}	1
10	10^{-6}	10^{-6}	10^{-6}	10^{-6}	1
11	10^{-2}	10^{-2}	10^{-2}	10^{-2}	1
12	10^{-7}	10^{-7}	10^{-7}	10^{-7}	g
13	10^{-3}	10^{-3}	10^{-3}	10^{-3}	g
14	10^{-1}	10^{-1}	10^{-1}	10^{-1}	g
15	10^{-7}	10^{-7}	10^{-7}	10^{-7}	g
16	10^{-3}	10^{-3}	10^{-3}	10^{-3}	g
17	10^{-1}	10^{-1}	10^{-1}	10^{-1}	g
18	10^{-7}	10^{-7}	10^{-7}	10^{-7}	g
19	10	10	10	10	g^{-1}
20	10^{-1}	10^{-1}	10^{-1}	10^{-1}	g
21	10^{-1}	10^{-1}	10^{-1}	10^{-1}	g
22	10	10	10	10	g^{-1}
23	10^{-5}	10^{-5}	10^{-5}	10^{-5}	g
24	10	10	10	10	g
25	10^{-7}	10^{-7}	10^{-7}	10^{-7}	g
26	10^{-3}	10^{-3}	10^{-3}	10^{-3}	g
27	10^{-1}	10^{-1}	10^{-1}	10^{-1}	g
28	10^{3}	10^{3}	10^{3}	10^{3}	g^{-1}
29	10^{-5}	10^{-5}	10^{-5}	10^{-5}	g^{-1}
30	10^{-3}	10^{-3}	10^{-3}	10^{-3}	g
31	10^{5}	10^{5}	10^{5}	10^{5}	g
32	10^{-3}	10^{-3}	10^{-3}	10^{-3}	1
33	10	10	10	10	1
34	10^{3}	10^{3}	10^{3}	10^{3}	1
35	10^{-3}	10^{-3}	10^{-3}	10^{-3}	1
36	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

38	Electricity	Q	Coulomb	Q	$\zeta 10$	$c^{-1}\zeta 10^{-1}$	$\eta^{-1}\zeta 10$	$c^{-1}\eta^{-1}\zeta 10^{-1}$
39	Electric moment	$\mathbf{Q} = QL$	Coulomb-meter	QL	$\zeta 10^{-1}$	$c^{-1}\zeta 10^{-3}$	$\eta^{-1}\zeta 10^{-1}$	$c^{-1}\eta^{-1}\zeta 10^{-3}$
40	Electric linear density	$q = QL^{-1}$	Coulomb per meter	QL^{-1}	$\zeta 10^{3}$	$c^{-1}\zeta 10$	$\eta^{-1}\zeta 10^{3}$	$c^{-1}\eta^{-1}\zeta 10$
41	Electric surface density	$\sigma = QS^{-1}$	Coulomb per square meter	QL^{-2}	$\zeta 10^{5}$	$c^{-1}\zeta 10^{3}$	$\eta^{-1}\zeta 10^{5}$	$c^{-1}\eta^{-1}\zeta 10^{3}$
42	Electric volume density	$\delta = QV^{-1}$	Coulomb per stere	QL^{-3}	$\zeta 10^{7}$	$c^{-1}\zeta 10^{5}$	$\eta^{-1}\zeta 10^{7}$	$c^{-1}\eta^{-1}\zeta 10^{5}$
43	Electronic ratio	$\upsilon = QM^{-1}$	Coulomb per kilogram	$QL^{2}P^{-1}T^{-3}$	$\zeta 10^{4}$	$c^{-1}\zeta 10^{2}$	$\eta^{-1}\zeta 10^{4}$	$c^{-1}\eta^{-1}\zeta 10^{2}$
44	Electrochemical equivalent	$\mathcal{K} = MQ^{-1}$	Kilogram per coulomb	$PT^{3}Q^{-1}L^{-2}$	$\zeta^{-1}10^{-4}$	$c\zeta^{-1}10^{-2}$	$\eta\zeta^{1-}10^{-4}$	$c\eta\zeta^{-1}10^{-2}$
45	Piezo-electric constant	$\mathbf{q} = Q\mathbf{F}^{-1}$	Coulomb per (joule per meter)	$QLP^{-1}T^{-1}$	$\zeta 10^{6}$	$c^{-1}\zeta 10^{4}$	$\eta^{-1}\zeta 10^{6}$	$c^{-1}\eta^{-1}\zeta 10^{4}$
46	Electric current	$I = QT^{-1}$	Ampere	QT^{-1}	$\zeta 10$	$c^{-1}\zeta 10^{-1}$	$\eta^{-1}\zeta 10$	$c^{-1}\eta^{-1}\zeta 10^{-1}$
47	Electric current density	$\mathbf{i} = IS^{-1}$	Ampere per square meter	$QT^{-1}L^{-2}$	$\zeta 10^{5}$	$c^{-1}\zeta 10^{3}$	$\eta^{-1}\zeta 10^{5}$	$c^{-1}\eta^{-1}\zeta 10^{3}$
48	Electromechanical force-factor	$\mathbf{F}_m = \mathbf{F}I^{-1}$	Volt-second per meter	$PT^{2}Q^{-1}L^{-1}$	$\zeta^{-1}10^{-6}$	$c\zeta^{-1}10^{-4}$	$\eta\zeta^{-1}10^{-6}$	$c\eta\zeta^{-1}10^{-4}$
49	Electro-acoustic force-factor	$\mathbf{F}_a = \mathbf{p}I^{-1}$	Volt-second per stere	$PT^{2}Q^{-1}L^{-3}$	$\zeta^{-1}10^{-2}$	$c\zeta^{-1}$	$\eta\zeta^{-1}10^{-2}$	$c\eta\zeta^{-1}$
50	Electric potential	$E = WQ^{-1}$	Volt	PTQ^{-1}	$\zeta^{-1}10^{-8}$	$c\zeta^{-1}10^{-6}$	$\eta\zeta^{-1}10^{-8}$	$c\eta\zeta^{-1}10^{-6}$
51	Electric field	$\mathbf{E} = EL^{-1}$	Volt per meter	$PTQ^{-1}L^{-1}$	$\zeta^{-1}10^{-6}$	$c\zeta^{-1}10^{-4}$	$\eta\zeta^{-1}10^{-6}$	$c\eta\zeta^{-1}10^{-4}$
52	Electric capacity	$C = QE^{-1}$	Farad	$Q^{2}P^{-1}T^{-1}$	$\zeta^{2}10^{9}$	$c^{-2}\zeta^{2}10^{5}$	$\eta^{-2}\zeta^{2}10^{9}$	$c^{-2}\eta^{-2}\zeta^{2}10^{5}$
53	Electric capacitivity	$\kappa = CL^{-1}$	Farad per meter	$Q^{2}P^{-1}T^{-1}L^{-1}$	$\zeta^{2}10^{11}$†	$c^{-2}\zeta^{2}10^{7}$†	$\eta^{-2}\zeta^{2}10^{11}$	$c^{-2}\eta^{-2}\zeta^{2}10^{7}$
54	Electric susceptibility	$\alpha = \kappa\text{-}\kappa_0$	Farad per meter	$Q^{2}P^{-1}T^{-1}L^{-1}$	$\zeta^{2}10^{11}$‡	$c^{-2}\zeta^{2}10^{7}$‡	$\eta^{-2}\zeta^{2}10^{11}$	$c^{-2}\eta^{-2}\zeta^{2}10^{7}$
55	Electric displacement	$\mathbf{D} = \kappa\mathbf{E}$	Coulomb per square meter	QL^{-2}	$\zeta 10^{5}$ ‡	$c^{-1}\zeta 10^{3}$‡	$\eta^{-1}\zeta 10^{5}$	$c^{-1}\eta^{-1}\zeta 10^{3}$
56	Electric polarization	$\mathbf{P} = \alpha\mathbf{E}$	Coulomb per square meter	QL^{-2}	$\zeta 10^{5}$	$c^{-1}\zeta 10^{3}$	$\eta^{-1}\zeta 10^{5}$	$c^{-1}\eta^{-1}\zeta 10^{3}$
57	Electric flux	$\Psi = \mathbf{D}S$	Coulomb	Q	$\eta^{-2}\zeta 10$	$c^{-1}\eta^{-2}\zeta 10^{-1}$	$\eta^{-1}\zeta 10$	$c^{-1}\eta^{-1}\zeta 10^{-1}$
58	Electric resistance	$R = EI^{-1}$	Ohm	$PT^{2}Q^{-2}$	$\zeta^{-2}10^{-9}$	$c^{2}\zeta^{-2}10^{-5}$	$\eta^{2}\zeta^{-2}10^{-9}$	$c^{2}\eta^{2}\zeta^{-2}10^{-5}$
59	Electric resistivity	$\rho = LR$	Meter-ohm	$PT^{2}Q^{-2}L$	$\zeta^{-2}10^{-11}$	$c^{2}\zeta^{-2}10^{-7}$	$\eta^{2}\zeta^{-2}10^{-11}$	$c^{2}\eta^{2}\zeta^{-2}10^{-7}$
60	Electric conductance	$G = IE^{-1}$	Mho	$Q^{2}P^{-1}T^{-2}$	$\zeta^{2}10^{9}$	$c^{-2}\zeta^{2}10^{5}$	$\eta^{-2}\zeta^{2}10^{9}$	$c^{-2}\eta^{-2}\zeta^{2}10^{5}$
61	Electric conductivity	$\gamma = GL^{-1}$	Mho per meter	$Q^{2}P^{-1}T^{-2}L^{-1}$	$\zeta^{2}10^{11}$	$c^{-2}\zeta^{2}10^{7}$	$\eta^{-2}\zeta^{2}10^{11}$	$c^{-2}\eta^{-2}\zeta^{2}10^{7}$
62	Electric inductance	$\mathfrak{L} = RT$	Henry	$PT^{3}Q^{-2}$	$\zeta^{-2}10^{-9}$	$c^{2}\zeta^{-2}10^{-5}$	$\eta^{2}\zeta^{-2}10^{-9}$	$c^{2}\eta^{2}\zeta^{-2}10^{-5}$
63	Electric inductivity	$\chi = \mathfrak{L}L^{-1}$	Henry per meter	$PT^{3}Q^{-2}L^{-1}$	$\zeta^{-2}10^{-7}$	$c^{2}\zeta^{-2}10^{-3}$	$\eta^{2}\zeta^{-2}10^{-7}$	$c^{2}\eta^{2}\zeta^{-2}10^{-3}$
64	Magnetomotive force	$\mathfrak{F} = NI$	Ampere-turn	QT^{-1}	$\eta^{-2}\zeta 10$	$c^{-1}\eta^{-2}\zeta 10^{-1}$	$\eta^{-1}\zeta 10$	$\eta^{-1}\zeta 10$
65	Magnetic field	$\mathbf{H} = \mathfrak{F}L^{-1}$	Ampere-turn per meter	$QT^{-1}L^{-1}$	$\eta^{-2}\zeta 10^{3}$	$c^{-1}\eta^{-2}\zeta 10$	$\eta^{-1}\zeta 10^{3}$	$\eta^{-1}\zeta 10^{3}$
66	Magnetic pole	$m = \mathbf{FH}^{-1}$	Volt-second per turn	$PT^{2}Q^{-1}$	$\eta^{2}\zeta^{-1}10^{-8}$	$c\eta^{2}\zeta^{-1}10^{-6}$	$\eta\zeta^{-1}10^{-8}$	$\eta\zeta^{-1}10^{-8}$
67	Magnetic moment	$\mathbf{m} = mL$	(Volt-second per turn)-meter	$PT^{2}Q^{-1}L$	$\eta^{2}\zeta^{-1}10^{-10}$	$c\eta^{2}\zeta^{-1}10^{-8}$	$\eta\zeta^{-1}10^{-10}$	$\eta\zeta^{-1}10^{-10}$
68	Magnetic flux	$\Phi = ETN^{-1}$	Volt-second per turn	$PT^{2}Q^{-1}$	$\zeta^{-1}10^{-8}$	$c\zeta^{-1}10^{-6}$	$\eta\zeta^{-1}10^{-8}$	$\eta\zeta^{-1}10^{-8}$
69	Magnetic flux density	$\mathbf{B} = \Phi S^{-1}$	(Volt-second per turn) per square meter	$PT^{2}Q^{-1}L^{-2}$	$\zeta^{-1}10^{-4}$	$c\zeta^{-1}10^{-2}$	$\eta\zeta^{-1}10^{-4}$	$\eta\zeta^{-1}10^{-4}$
70	Magnetic reluctance	$\mathfrak{R} = \mathfrak{F}\Phi^{-1}$	Henry^{-1}-turn^{2}	$Q^{2}P^{-1}T^{-3}$	$\eta^{-2}\zeta^{2}10^{9}$	$c^{-2}\eta^{-2}\zeta^{2}10^{5}$	$\eta^{-2}\zeta^{2}10^{9}$	$\eta^{-2}\zeta^{2}10^{9}$
71	Magnetic permeance	$\mathfrak{P} = \Phi\mathfrak{F}^{-1}$	Henry per turn^{2}	$PT^{3}Q^{-2}$	$\eta^{2}\zeta^{-2}10^{-9}$	$c^{2}\eta^{2}\zeta^{-2}10^{-5}$	$\eta^{2}\zeta^{-2}10^{-9}$	$\eta^{2}\zeta^{-2}10^{-9}$
72	Specific magnetic permeance	$\nu = \mathfrak{P}L^{-1}$	(Henry per turn^{2}) per meter	$PT^{3}Q^{-2}L^{-1}$	$\eta^{2}\zeta^{-2}10^{-7}$†	$c^{2}\eta^{2}\zeta^{-2}10^{-3}$†	$\eta^{2}\zeta^{-2}10^{-7}$	$\eta^{2}\zeta^{-2}10^{-7}$
73	Magnetic susceptibility	$\beta = \nu\text{-}\nu_0$	(Henry per turn^{2}) per meter	$PT^{3}Q^{-2}L^{-1}$	$\eta^{4}\zeta^{-2}10^{-7}$‡	$c^{2}\eta^{4}\zeta^{-2}10^{-3}$‡	$\eta^{2}\zeta^{-2}10^{-7}$	$\eta^{2}\zeta^{-2}10^{-7}$
74	Magnetic polarization	$\mathbf{I} = \beta\mathbf{H}$	(Volt-second per turn) per square meter	$PT^{2}Q^{-1}L^{-2}$	$\eta^{2}\zeta^{-1}10^{-4}$	$c\eta^{2}\zeta^{-1}10^{-2}$	$\eta\zeta^{-1}10^{-4}$	$\eta\zeta^{-1}10^{-4}$

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* **Multiply by the tabulated value for conversion of a numerical magnitude into definitive units.**
Divide by the tabulated value for conversion of each letter of a complete literal equation into definitive units.

† **In the cgse and cgsm systems the dielectric constant K and the permeability μ are generally used rather than the capacitivity κ and the specific permeance ν of the definitive system. The symbols K and μ represent pure numerics: the relative capacitivity and the relative specific permeance of the medium with respect to free space.**

‡ **Usage varies.**

g = local acceleration of gravity = 9.7807 to 9.8326 meters per second per second, on the earth's surface.
c = velocity of light = 2.99796 × 10^{8} meters per second, approximately.
ζ = $\sqrt{}$(ratio definitive ohm to "absolute-practical" ohm).
η = $\sqrt{(4\pi)}$ = 3.544908.

with a single, definitive system of units instead of starting with multiple systems. This would conserve mental energy. The definitive system meets the needs of both industry and science without sacrificing the precision, stability, coherence and completeness demanded by science; the simplicity of its familiar units is a distinct advantage for science.

HISTORICAL BACKGROUND OF DEFINITIVE UNITS

The preceding discussion of definitive units has been based, not on quoted authorities, but on sample counts of units in present use and the logical future needs of physical measurement. The authorities who gave us our present multiple systems of units, based on the cgs units, do not seem to have seriously considered a single, universal system. Single-system advocates have been less prominent but their point of view has, it seems to me, been logically supported. The practical importance of a single, universal system would justify a history of the idea, but a chronological outline with a few quotations is all that will be attempted at the present time.

1799. The meter and kilogram in platinum were definitely fixed and defined as the standards of length and weight by the French statute of December 10, 1799. This retained the gram of the provisional statute of 1795 as the basis of the nomenclature but substituted the kilogram as the physical standard. This inconsistency in nomenclature has continued to the present time. The definitive system gives the kilogram a factor-free name for optional use.

1833. Definitive electric and magnetic units had their beginnings in the publication of Gauss's so-called absolute unit for the magnetic pole and magnetic field. Being primarily a mathematician, Gauss simplified his formulas as much as possible by making the inverse-square law for magnetic poles factor-free. This was good mathematics but poor physics. It equated the product of two magnetic poles to the product of a force and the square of a distance. There was no justification for this at that time, nor is there any at the present time; it has been the source of much confusion. So also has been the use of the term "absolute." It is a remarkable fact that now, a hundred years after Gauss's magnetic unit was introduced, there is still confusion in the domain of magnetic units, and even disagreement as to the quantity which the unit name "gauss" should designate. At least four factors seem to have contributed to this situation. The magnetic pole chosen for the point of departure does not exist as a physical entity. The term "absolute" is misleading. The reduction of magnetism to mechanics by a factor-free inverse-square law is not justified. The millimeter and milligram, chosen in place of the meter and kilogram, do not constitute a uniform use of the fundamental metric units. None of these four features appears in the definitive system.

1851. Weber extended Gauss's magnetic unit system to include electric units. The comments on the units of Gauss and Weber, made in a recent German handbook, seem to be justified.

> "The peculiar development of the science of electricity caused C. F. Gauss and W. Weber to draw up systems of units from the theory, long before accurate measurements could be made. These units are called 'absolute' as opposed to the 'practical' units. It would be more correct to call them the 'theoretical' or even the 'impractical' units. For that they are. Nevertheless, no one will deny the genius of their discovery. These 'absolute' units were defined according to the third, impractical method—quite naturally because they were established before real precision methods were known. Fixed values were assigned to certain universal constants and thereby the units were determined which would not have occurred if it had been possible to make good measurements." [Gustav Mie, Elektrodynamik, 1932, p. 430-431 (translated).]

1861. Sir Charles Bright and Latimer Clark suggested to the British Association that a coherent system of units would be a great boon for both telegraphy and science (British Association paper, September, 1861, printed in Atlantic and Government Report on Submarine Cables, 1869, p. 49-50). Their specifications reflected their practical experience with submarine cables: the Daniell's cell was taken as the unit of potential; a plate condenser a meter by a meter by a millimeter was the unit of capacity; the charge supplied to this condenser by the Daniell's cell was the unit of electricity; the flow of this unit of electricity in a second was the unit of current; the resistance through which the Daniell's element drives this current, as shown by a galvanometer, was the unit of resistance. Their system required only the equipment found in telegraph offices. It was all perfectly simple, practicable and easily understandable. If they had specified, not the dimensions of the condenser, but its energy when charged to the unit of potential as the energy of a kilogram with a velocity of a meter per second, they would have had almost exactly our present international units. They suggested that a committee on electric units be appointed by the British Association for the Advancement of Science.

1862. Into the first of the thirty-nine reports of the British Association Committee on Standards of Electrical Resistance, William Thomson introduced energy as a connecting link. This first annual report settled the main feature of electric units as it has continued down to the present time; namely, two systems of units: a material system for the telegraph engineer, an abstract system for the theoretical scientist. The original underlying thought seemed to be that by using two systems side by side, their differing excellences would tend to add, their differing defects would tend to cancel. Seventy years actual use, however, shows that there has been a tendency for the excellences to cancel and the defects to add. The definitive system abandons this dualism and presents a single system of units for universal use.

1864. The difficulties of measurement based on Weber's abstract units were increasingly realized as the British Association Committee's experimental work lagged.

> "It has never been proposed that the British-Association standard should be considered as representing exactly an absolute measurement; whatever may be the state of science, any such pretension could not be well founded, for all that can be done at any time, by the very greatest care, is to reduce the possible error to less than a certain amount. The amount of probable error in the present determination is so small as to be insignificant for any of the present purposes of science, and will always remain insignificant for any practical applications. For these applications it is chiefly important that every copy of the standard, whatever that may be, should be accurately made—a condition which is quite unaffected by the greater or less discrepancy between the standard and true absolute measurement." (British Association Reports on Electrical Standards, p. 161-162.)

The definitive system conforms to the requirement that all copies of resistance standards shall be as accurately made as possible to the same unchanged magnitude; it relegates to other apparatus of lower precision, such as ammeters, voltmeters and wattmeters, the corrections which may be required from time to time in securing a more precisely coherent system of units.

1865. The B.A. ohm was issued, the committee having "decided to rest content with the results of the experiments now completed" in the belief that its ohm had a probable error of not over 0.08 per cent. The actual error was about 1.2 per cent, or about 15 times as large. No standard for current, potential or other quantity was issued before the committee disbanded in 1870.

1875. J. D. Everett made this claim in his preface to "Illustrations of the C.G.S. System of Units":

> "The most important experimental data relating to each subject are concisely presented on *one uniform scale*—a luxury hitherto unknown to the scientific calculator."

His "one uniform scale" included, however, the cgsm, cgse and "absolute-practical" systems. The real luxury of uniformity is presented by the definitive system.

1881. The International Electrical Congress in Paris adopted the mercury column for a new material standard ohm and continued the use of the abstract "absolute-practical" ohm. Helmholtz thus carried his point for the mercury ohm; Kelvin carried his point for the abstract unit; together they continued the unfortunate, useless burden of a duality of material and abstract units for the ohm, which is still with us. The "absolute-practical" ampere was adopted, which could not agree with the mechanical watt and required an electric watt. The centimeter was adopted without discussion. Uniformity and precision in weights and measures, however, which had been internationally subscribed to six years earlier, called for the adoption of the meter and not the centimeter, for the adoption of the kilogram and not the gram. The uniform system would have been the meter-kilogram-second-ohm system and not the cgsm system.

1882. Heaviside began pointing out the absurdity of the 4π eruption and his remedy for it. In 1891, he went over to rational units exclusively. Theoretical electromagnetism has, to a great extent, followed him. This has added to the unit confusion; our seven-fold multiplicity of systems draws this comment from a recent German writer:

> "Unfortunately, so far, no uniform manner of writing has been successfully proposed in the theoretical science of electricity. There is a large number of various systems of units, and the formulas are written differently in each. In addition to the two old theoretical systems of units there are two, more recent ones, which are characterized by the following values of ϵ_0 and μ_0: (a) electrostatically, $\epsilon_0 = 1$, $\mu_0 = 1/c^2$; (b) electromagnetically, $\epsilon_0 = 1/c^2$, $\mu_0 = 1$. They are introduced in order to remove the unintelligible and troublesome 4π from the fundamental formulas. In addition, in each of the two groups of theoretical systems of units there is a mixed system where some quantities are measured electrostatically, and others electromagnetically; as a result an external symmetry, which is pleasing to the eye, is supposed to be obtained in Maxwell's equations. In this way we have six different systems of units, all of which are found in theoretical literature. Moreover, there is a seventh system, the system of practical units, which is the only one of concern to experimental physicists; even this system is ignored by theorists. With this system it would be very easy to write the formulas of theoretical physics so that they are valid at once for all the various systems of measurement, except the mixed systems which are inconsistent in themselves. We should only have to decide to recognize the undeniable fact that all electrical measurements are based on two fundamental units, that of the voltage and that of the charge. Of course, from this fact we should have to draw a conclusion which cannot be avoided but which seems to be very inconvenient for theorists, namely that there are two essentially different methods of measurement for the electric as well as the magnetic field, and accordingly that there are also two essentially different units." [Gustav Mie, Elektrodynamik, 1932, p. 433-434 (translated).]

1887. The ampere-turn was in use by this date.

1891. The practical system of measurements suggested by John Perry included by name the watt, ampere, volt and ampere-turn; he recommended the volt-second magnitude be given a name; he made other suggestions, each of which agrees closely with the definitive system provided only the meter be substituted where he used the centimeter:

> "I would suggest that the practical unit of magnetic flux (or induction or force), be 10^8 C.-G.-S. units, and that it receive a name. That the magnetic permeability of air shall no longer be assumed to be unity, but, in the practical system of measurement, be tabulated like the permeability of any other substance; —the permeability of air will be $4\pi \times 10^{-9}$, and that in future no substance shall have unit permeability. That the unit of total magnetomotive force in a magnetic circuit be 1 ampere turn. The unit of magnetomotive force gradient would be 1 ampere turn per centimetre. . . . ." (Practical Electro-Magnetic Units. *Electrician* (London), July 31, 1891, p. 355.)

1893. At Chicago, the international ohm was adopted in the belief, apparently, that it agreed with the "absolute-practical" ohm within 100 parts in a million. The actual error is now known to be about 460 ± 20 parts in a million, or about 4.6 times as great. Preliminary reports of our newest measurements (1927-1933) differ by 50 parts in a million from the accepted value which was 1.000510 ± 0.000020 [R. T. Birge, *Reviews of Modern Physics* 1: 16 (1929)]. These two recent values thus differ by two and one-half times the probable error assigned to each of the values. The three ratios 15, 4.6 and 2.5 for 1865, 1893 and 1933, respectively, are decreasing but still indicate over-optimism on the part of experimentalists.

1895. Magnetic units were actively discussed during this year, Heaviside declaring that there was no way out of the 4π difficulty "but by my radical cure." He characterized the 4π eruption as absurd, arbitrary, injurious, inconvenient, irrational, mischievous, obtrusive, perverse, preposterous, ridiculous, stupid, unfortunate, unnecessary and unspeakable. It was said that he "gets rid of the 4π difficulty by stuffing it into a new corner." This critic seems to have thought that Heaviside should either altogether have banished the 4π from electromagnetism or left it undisturbed, on the ground that its position made but little difference. No one can eliminate the 4π from electromagnetic theory. The geometry of the sphere brings it in because electromagnetic effects expand in concentric spheres. The position of the 4π is important. It is easier to work with the 4π's if they are associated with the spheres which introduce them. This is what Heaviside attempted to do. But he needlessly sacrificed the existing shop electric units; he stopped short of considering either an empirical ohm or the advantages of one system of units. He did not go far enough to secure the adherence of either the experimental physicist or the engineer. Heaviside's equations have come into wide use; they were his permanent contribution. He made the world feel, moreover, less satisfied with the British Association units. Thus:

> "And yet we are not sure that Mr. Heaviside is not right, even though it be a case of Heaviside *contra mundum*. Some day, when point poles, and surface units, and action-at-a-distance shall have vanished into the limbo of mediaeval absurdities, and when electricians have learned to think of *action in the medium,* we shall wonder how that foolish old B.A. Committee of 1862, and that feeble International Congress of 1881 ever blundered into the C.G.S. system. And then we shall turn to our Heaviside, who tried to save us from ourselves. But in a world of practical issues, of commercial interests, and of men of business, not even for the sake of the more enlightened generation that will follow, can we afford to contemplate such revolutionary measures. To recommend them piecemeal, even by the inspired voice of a British Association Committee, would only have the effect of indefinitely shelving more pressing, though moderate, reforms. We therefore, and with a genuine regret, set them aside as too good for this unheroic age.
>
> "Our correspondents who are engineers are also nearly agreed amongst themselves in another point—namely, that as unit of magnetomotive force the *ampere-turn* should be taken as the unit. The $4\pi/10$ factor must needs come in somewhere, either here or in the definition of the third quantity, which, whether considered as a reluctance or a permeance, comes in as the ratio of the two others. Engineers who have to deal with construction prefer to take *ampere-turns* simply. As Mr. Snell puts it, both the ampere and the turn are shop quantities; and the relation between *ampere-turns* and the resulting flux-density is in practice habitually taken off from a graphic curve that embodies the result of pure experiment. In that case no new name is wanted for the unit, as the *ampere-turn* is itself the name." (Magnetic Units. From a leader in *Electrician* (London), September 13, 1895, p. 640-642.)

In the definitive system the mechanical, electric and magnetic units are all derived by means of factor-free defining equations from four empirical primary units. No 4π is introduced by these two classes of conventions. Wherever a 4π occurs in the use of the definitive system, it has of necessity been introduced by the geometry of the problem under consideration.

1900. F. J. Rogers advocated the meter-kilogram-second system (M.K.S.), including the watt, joule and "large Dyne," *i. e.,* the joule per meter, as being a harmonious mechanical system which is much more convenient than the cgs system [*Physical Review* 11: 115-116 (1900)].

1901. "The mass of the international kilogram is taken as unity for the international system of weights and measures" by decision of the International Committee on Weights and Measures. This followed the French metrical system based on the French law of December 10, 1799, which adopted the kilogram as the definite standard of weight. To make the position of the kilogram in the metric system clearer, it should now have, at least for optional use, a prefix-free name as proposed in the definitive system.

1901. G. Giorgi proposed an "absolute metre-kilogramme-second system" (M.Kg.S.), including the volt, ampere, watt, coulomb, weber, ohm, mho, farad and henry, and he is still actively advocating its adoption.

> "I frame the practical units into an absolute system, and all other absolute systems are abolished. . . . .
>
> "The fundamental units of the electric system are not specific but concrete ones. Thus in the future, the so-called absolute determinations of the ohm will be interpreted as measurements of the ether inductivity." (G. Giorgi, *Electrical World*, September 6, 1902.)

He used the same names for the units of different quantities with the same physical dimensions, such as current and magnetomotive force, even though he adhered to the practice of using different symbols for these different quantities. For the definitive system it seems desirable to have different unit names as well as different symbols.

It is also important to clearly recognize the present impossibility of a prototype ohm.

This was not recognized by Giorgi in the above 1902 statement or in his most recent 1932 and 1933 papers (*Elettrotecnica*, May 5, 1932, and February 15, 1933).

1904. David Robertson independently proposed the meter-kilogram-second-ohm (or -coulomb) system as an extension of the practical electric system for universal use. He advocated the gradual lapse of all other units and their ultimate abolition even for those "unable to imagine any scientific work being possible without the C.G.S. system." As the standard for the fourth fundamental quantity he took the legalized ohm and pointed out that the methods hitherto used for determining resistances in absolute measure became the means for determining the permeability of air. He also noted that the dimensions are all rationalized if the coulomb or ampere is chosen in place of the ohm [*Electrician* (London), April 24, 1904, p. 24]. The definitive system is based on the same legalized ohm and the four fundamental quantities are considered an optional choice to be settled so as to simplify the immediate problem in hand.

1917. Edward Bennett vigorously advocated a single system of units, the centimeter, gram-seven, second (C.G.S.S.) system. I always read his preface with pleasure. But he adopted the centimeter and not the meter to go with the second, watt and ohm. Evidently, he was thinking as an electrical engineer and scientist, and not as a representative of the vastly larger metric world, when he explained his preference for the centimeter thus:

> "Prof. G. Giorgi has advocated the use of the meter, the kilogram and the second as the mechanical units of the practical system. . . . . In the estimation of the writer, the M.K.S. system labors under a disadvantage in that its use would entail a departure from the well established practice of thinking and writing of flux densities per square centimeter and of gradients per centimeter. In the case of such an important and ever present quantity as length, a great deal is gained by adhering in the Practical System to the unit used in the E.S. and E.M. systems—namely the centimeter." [A Digest of the Relations Between the Electrical Units, and of the Laws Underlying the Units. *Bulletin of the University of Wisconsin,* No. 880, p. 14 (1917).]

At this point I may add that it is incorrect to cite J. H. Dellinger as ever having been an advocate of the centimeter, gram-seven, second system for universal use. He considered its usefulness limited to electromagnetism on account of the undesirable values of the unit of mass and some other mechanical units. In 1925 he wrote me, ". . . . I pointed out that the international electrical units are the ones actually used. . . . I considered that, as actually used, it was based on the international ohm, ampere, centimeter and second . . . . therefore its usefulness was limited to electromagnetism. By your choice of the meter and kilogram you have set forth a system which is applicable throughout physics."

Of course the present paper claims much more: that the definitive system is applicable throughout physics, industry, commerce and trade, everywhere. No use for units which have been based upon the meter is intentionally excluded.

1932. Report No. 2 of the American Institute of Electrical Engineers on Proposed American Standard Definitions of Electrical Terms contains a section of over three pages (p. 31-34) devoted to Units and Systems of Measurement. This supplies a striking exhibition of the multiplicity of systems of electric units which are now imposed upon engineers as well as physicists. The electric units actually used in the shop and laboratory are defined quite simply on the last half page. Great complexity and confusion are introduced, however, by the six systems of units which underlie these shop units. British units present nothing as complicated and confusing.

1933. The Advisory Committee on Electricity to the International Committee on Weights and Measures made formal recommendations, in February (*Bureau of Standards Technical News Bulletin,* March, 1933), based on its findings: that for the practical use of laboratories of precision there is reason to assign to standards of resistance values expressed to one part in a million; that it may not be possible, at present, to attain a precision better than ten parts in a million in absolute determinations; that a provisional establishment of a value can first be made in the year 1935 with possible readjustments of this value (reading between the lines), from time to time, as the precision of absolute measurements is improved in the future. This seems to call for an empirical assignment of the last significant figure of the standard for the ohm. The findings and recommendations have much in common with the British Association statement of 1864.

This historical outline has brought out a number of the difficulties in our present multiple systems of units and the advantages which may be reasonably expected from a change to a single, preferred system. For this single system there have been sponsors for each of the several features of the definitive system, including the use of the meter, kilogram, ampere-turn, and the legalized ohm.

SUMMARY

I believe that this discussion, based upon actual counts of the units now in use, has shown that:

1. A conservative plan is presented for linking the most popular units to form a single, convenient definitive system for preferred use.
2. Once initiated, transition to the definitive system would be simple because it would involve little more than an increase of possibly one-third in the use of popular units and the dropping of many inconvenient, unfamiliar units.
3. The use of definitive units would clear up the long-standing confusion in magnetic units and nomenclature.
4. The great advantages in the use of a single system, everywhere, by everyone, for every purpose, including shopping, marketing, commerce, industry, engineering, experimental science and theoretical science, could be realized in the near future by the adoption of the definitive system.

Apparently, the outstanding difficulty in initiating the universal use of the definitive system is the wide-spread feeling among scientists that there is something particularly basic, true and even sacred about the cgs systems. For overcoming this fetish, I know of no more promising occasion than the assumption of jurisdiction over electric units by the international Bureau of Weights and Measures. This jurisdiction will include, in particular, the meter, the kilogram, the ohm and the volt. The Bureau will doubtless recommend that they be legalized as the units for length, mass, electric resistance and electromotive force by all nations adhering to the Metric Convention. The International Bureau should naturally favor a system of units conforming directly to these four units which it sponsors. A system based on the meter, kilogram, second and ohm does so conform. None of the cgs systems was built up in this way without the use of decimal multipliers. The definitive system does conform to the four units sponsored by the International Bureau. My formal recommendations are that:

1. The International Bureau of Weights and Measures should take full advantage of the unique opportunity presented by its expanding activities to introduce complete uniformity into the metrical units for mechanics, electricity and magnetism, by designating the definitive system as its preferred system of metrical units.
2. The International Bureau should give the kilogram, which is its unit of mass, a prefix-free name for optional use, so that the nomenclature will include prefix-free names uniformly for all fundamental definitive units.

THE ESTABLISHMENT AND MAINTENANCE OF THE ELECTRICAL UNITS[1]

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Electrical units were first established about a century ago. Since that time many changes have occurred in these units. In order to obtain an appreciation of the methods which are now used for establishing and maintaining them, an historical outline will be given to indicate the methods which have been employed for this purpose. This will be followed by a description of the methods now employed and a statement of the accuracy obtained by the various national and international laboratories which share this responsibility.

HISTORICAL

The first electrical measurements were made by comparing an unknown quantity with some arbitrarily selected quantity of the same kind which was chosen as a standard. For example, the first measurements of resistance were made by comparing the unknown resistance with the resistance of a particular sample of copper wire which was kept as the standard. In 1833, just one hundred years ago, Gauss published a paper on the determination of the strength of the earth's magnetic field in terms of mechanical units. He called this type of measurement an "absolute measurement," a term which is still applied.

In 1837, Pouillet devised the tangent galvanometer by which an electric current could be measured in terms of the diameter of a coil of wire and the strength of the earth's magnetic field and hence, from Gauss' experiment, in terms of mechanical units. About the same time, Siemens suggested the use of a column of mercury of definite mechanical dimensions as defining a unit of resistance. Thus with the ohm and the ampere defined in terms of mechanical units and the properties of certain media, and with the volt derived from these by the application of Ohm's law, the three most important electrical units were definitely established. However, in 1851, Weber showed that, by accepting the doctrine of the conservation of energy, two different systems of units could be devised, each of which would be based on the mechanical units and would require the assigning of a numerical value to a property of a single medium, namely, a vacuum. One of the systems assigned an arbitrary value to the permeability of a vacuum, the other to the dielectric constant of a vacuum.

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[1] Publication Approved by the Director of the Bureau of Standards of the U. S. Department of Commerce.

The British Association Committee on Electrical Units and Standards gave careful consideration to the various proposals and in 1863 adopted the electromagnetic units as outlined by Weber. They decided to define the fundamental units in terms of the c.g.s. mechanical units, assigning the value of unity to the permeability of a vacuum and adopting a system of "practical" units in which each unit was related to the corresponding unit of the fundamental system by some power of ten. In the reports of the Committee, there is little discussion concerning the ampere or volt. Apparently, the tangent galvanometer was satisfactory for current measurements, and the electromotive force could always be measured in terms of the fall of potential of a known current over a known resistance. Careful consideration was given, however, to the ohm. The Committee decided to make an absolute determination by which to fix the value of the ohm in the system which had been adopted. Resistance standards were constructed and values based on the results of the absolute determination were assigned to them. However, the Siemens unit was still used in many laboratories, particularly in Germany.

It was not until the Paris Electrical Congress of 1881 that an international agreement was reached. This agreement was in the form of a compromise, in which the fundamental basis of the units was that adopted by the British Association Committee, but the practical definition of the unit of resistance was in terms of a column of mercury having the cross-section proposed by Siemens but of such length that the resistance would correspond to the absolute unit. This Congress proposed that every ten years a Congress should be held at which any necessary change in the length of the mercury column representing the ohm would be decided upon.

A great advance toward the establishment of uniform electrical units was made at the Electrical Congress held in Chicago just 40 years ago. At that time the so-called international units were adopted. That action may be considered the starting point of our present units. A brief consideration of conditions as they were at that time and as we now find them will aid in understanding the problems which have arisen in the meantime.

In 1893, there was only one national laboratory devoted to the maintenance of units, namely, the Physikalisch-Technische Reichsanstalt of Germany. Moreover, there was little demand for measurements of high precision as we know them today. An accuracy of one-tenth of one per cent was considered sufficient for even the most refined measurements. Resistance standards were mostly made from German silver wire. It was generally assumed that any well equipped laboratory could readily calibrate its standards by setting up a mercury ohm, but most laboratories preferred instead to procure its standards from a reputable manufacturer. The Clark cell was just displacing the Daniell cell as a standard of electromotive force. The tangent galvanometer was still a respected instrument for measuring electric current, although it was rapidly losing caste. Its place was being taken by the silver or copper voltameter, which was used in many laboratories as a means of calibrating ammeters.

Contrasted with the above, there are now at least six countries having laboratories devoted to the maintenance of the electrical units, namely, England, France, Germany, Japan, Russia and the United States. The precision of electrical measurements has increased until now an accuracy of one part in a million is not uncommon. Resistance standards are mostly constructed from manganin and laboratories which wish to secure the highest accuracy have their standards certified, either directly or indirectly, by one of the national laboratories. The Weston cell has completely displaced the Clark cell and most laboratories require that their cells be certified by one of the national laboratories. Precision measurements of electric current are always made by determining the fall in potential produced by it in a known resistance.

METHODS OF ESTABLISHING ELECTRICAL UNITS

In order to establish the electrical units in the electromagnetic system, it is customary to make absolute measurements of an electric current and of an electrical resistance. These two quantities have been chosen because they can be most accurately measured in terms of mechanical units. The relationships between the fundamental concepts and the experimental methods can well be shown by means of a series of very simple equations. If current, electromotive force, quantity and resistance are represented by I, E, Q and R respectively, if the mechanical units of force, energy, and power are represented by F, W, and P and if μ is the permeability of the medium surrounding the experimental apparatus and k a dimensionless constant which depends solely on the ratios of the linear dimensions of the apparatus, the fundamental relationships are the following:

$$\mu I^2 = kF \text{ (Ampère's law)}; \tag{1}$$

$$E = \frac{W}{Q} = \frac{P}{I} \text{ (conservation of energy)}; \tag{2}$$

$$R = \frac{E}{I} \text{ (Ohm's law)}. \tag{3}$$

The absolute value of the current is determined directly from Ampère's law (equation 1). However, for measuring the resistance, the three equations are combined so that

$$R = \frac{\mu P}{kF}. \tag{4}$$

Substituting the dimensional equations for P and F

$$R = \frac{\mu L}{kT} \tag{5}$$

where L is a length and T is a time. However, μL has the dimensions of an inductance. It follows that a resistance can be determined in terms of inductance and time, time being directly measured and inductance computed from the mechanical dimensions of the system.

Absolute Measurement of Current.—Equation (1) indicates that the absolute value of a current can be determined by measuring the force between conductors carrying currents. These forces depend upon the magnetic effects of the currents. An absolute measurement can also be made by determining the force between a current and a magnet. A third general method is that of comparing the magnetic field produced by a current with the magnetic field of the earth, as is done with a tangent galvanometer. This latter method was almost universally used in the measurements of current until 1880. However, for the accuracy now required, this method is not suitable, since the earth's magnetic field is always varying. All recent and precise measurements are based on the forces between conductors carrying currents.

Determinations of the absolute value of the ampere are now in progress at the National Physical Laboratory, the Reichsanstalt and the Bureau of Standards. Each laboratory has constructed a current balance or current weigher in which the electromagnetic force acting between two different parts of the same circuit is compared with a force produced by the gravitational attraction of the earth for a given mass.

Absolute Measurement of Resistance.—The absolute measurement of resistance has generally been accomplished by constructing a standard of inductance, the value of which can be computed from its measured dimensions. All parts of this apparatus and its surroundings must be constructed of materials having a permeability which is practically the same as that of a vacuum. In addition, there is required a measurement of time. Many different arrangements have been employed to introduce this quantity into the measuring scheme.

One of the most straightforward methods is that proposed by Lorenz and developed into a method of precision by F. E. Smith. The apparatus is a homopolar generator in which the induced electromotive force is compared directly with the drop in potential produced in a standard resistance by the current which flows through the field coils of the generator.

In recent years, alternating current methods have been employed for absolute determinations of the ohm. In these methods, either a self, or a mutual, inductor is so constructed that its inductance can be computed from its measured dimensions. The values of resistance standards are then determined in terms of the computed inductance and the unit of time.

MAINTENANCE OF ELECTRICAL UNITS BY WORKING STANDARDS

The experimental difficulties connected with the absolute measurement of the ohm and of the ampere are such that these determinations have been made at infrequent intervals. Between such determinations, it is necessary that the units be maintained by means of working standards. The working standards which are now universally used are manganin resistance coils and saturated cadmium cells (Weston cells).

For more than a quarter of a century, the national standardizing laboratories have cooperated in an effort to maintain the units with the highest possible precision. The laboratories of England, France, Germany, Japan, Russia and the United States have each maintained the units, and comparisons between these laboratories have been made on numerous occasions. As more data are available concerning the standards of the laboratories of England, Germany and the United States, the following discussion will be based on results reported by them.

Maintenance of the Unit of Resistance.—The unit of resistance is now maintained in the national laboratories by means of manganin resistance coils. Each laboratory has a considerable number of such coils, and the mean of a group is used to keep the value of the unit. At the German laboratory (the Reichsanstalt), the unit has been largely maintained by means of four manganin resistance standards, all of which have been under observation since 1893. The mean of the values of the four coils was assumed to be constant from 1896 until 1927. The relative values have changed appreciably as is shown [2] by the upper curves in Figure 1. From the curves, it appears that one coil has increased relatively to the mean by about 50 parts in 1,000,000; another has decreased by about the same amount; while the two others have changed but little with relation to the mean of the four.

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[2] von Steinwehr. Proceedings of the Paris International Electrical Congress of 1932, Vol. III: 25.

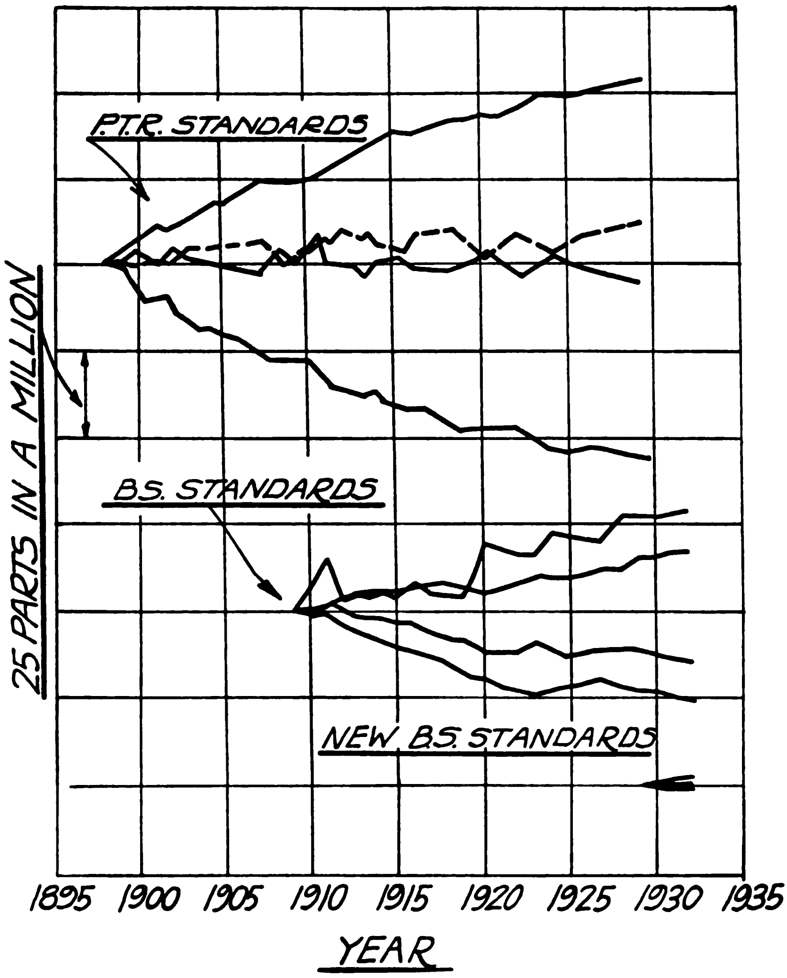

Fig. 1.—Changes in the resistance of standards relative to the maintained unit.

Note.—There are two reasons why the curves for the new B. S. standards are not comparable with those of the other standards. (1) The data of the new standards were taken immediately after they were constructed, while the other standards were well seasoned before the taking of data was started. (2) In the three years since their construction, the new B. S. standards have, on three occasions, been transported to and returned from various European laboratories; whereas each of the other standards has been carefully maintained in a single laboratory.

About 1908 the Bureau of Standards established its resistance unit by means of coils which were certified at the Reichsanstalt. Since that time the unit has been maintained by means of a selected group of ten one-ohm coils. An intercomparison of all the one-ohm coils of the Bureau is normally made once or twice a year, at which time the ten coils for the standard group are selected. The average value of the ten selected coils is taken to be the same as at the previous intercomparison. There are six coils which have been chosen in every intercomparison made since 1908. Curves for four of these coils are also shown in Figure 1. The values given are relative to the maintained unit. One coil has increased by 28 parts in 1,000,000, while another has decreased by 25 parts. The rate at which these coils have changed resistance is much the same as for the Reichsanstalt coils.

The resistance standards of the British, which are kept at the National Physical Laboratory, have shown changes of the same order as those of the Bureau.

In recent years a new type of coil has been developed at the Bureau of Standards which gives promise of being more stable than any of the previous types.[3] The curves on the first three coils constructed are also shown in Figure 1. While no relative change has as yet taken place in any of these coils of more than one or two parts in 1,000,000, it is too soon to be certain that they will remain stable over a long period of years. However, they are more stable immediately following construction than other types, and can be transported between distant laboratories with much less probability of change in value.

The above discussion refers to changes in the relative values of the working standards of the individual national laboratories. Consideration will now be given to changes which have occurred in the relative values of the resistance standards of these laboratories. In Figure 2 is shown for the national laboratories of England, Germany and the United States, the relative change in the standards by which the resistance unit is maintained in these laboratories. In constructing this chart it was assumed that all laboratories had the same value of the ohm in 1912 and that the mean value of the standards of the three laboratories has remained constant. If a laboratory made a change in its unit at a particular time, subsequent results have been changed to give the value that would have been obtained had the mean value of the standards been taken as constant. This chart indicates that resistance standards of the Bureau of Standards have increased in resistance about 20 parts in

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[3] Thomas, James L. New design of precision resistance standard. Bur. Standards J. Research 5: 295-304 (1930). (R. P. 201).

1,000,000 while those in the other laboratories have decreased about 10 parts in 1,000,000. That this was not the actual condition is indicated by the fact that within the last decade both the National Physical Laboratory and the Reichsanstalt have made comparisons with mercury ohm standards which indicate that the values of their working standards have increased about 30 parts in 1,000,000 since 1912. Hence, both of these laboratories have now changed their units from those shown in the chart. The chart has been prepared to show that even a laboratory which is giving careful attention to the maintenance of units cannot be certain that there is not a continuous drift in the value which it maintains by working standards.

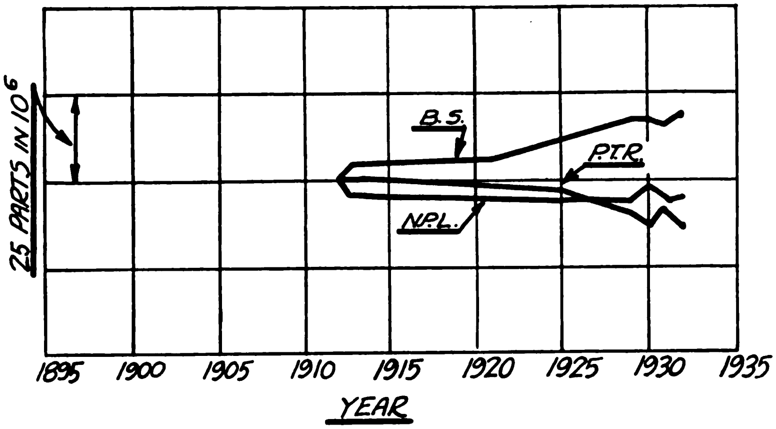

Fig. 2.—Variations of the units of resistance of three national laboratories: The mean values assumed constant.

In most of the international comparisons, results which are accurate to one part in a million have not been possible. With the Reichsanstalt type of coils, there may be an appreciable change in resistance caused by humidity changes. As an example, of the two coils which were brought to the Bureau of Standards from the Reichsanstalt in 1910 for the international comparison of units, one changed by 13 parts in 1,000,000 and the other by 17 parts during the month they were under observation. The sealed coils of the Bureau of Standards are not subject to humidity changes but nevertheless shown appreciable changes during transportation from laboratory to laboratory. Before 1930, intercomparisons could not be depended upon closer than 5 parts in 1,000,000. Beginning in 1930, several intercomparisons have been made using the new type of Bureau of Standards coils. These coils have shown practically no change on being transported from laboratory to laboratory. It seems probable that intercomparisons can now be made with an accuracy of one to two parts in 1,000,000.

The results of the latest intercomparison, made in the summer of 1932, show that a coil to which a value of one ohm was assigned at the Bureau of Standards would have been assigned a value of 0.999984 ohm at the Reichsanstalt and 1.000002 ohm at the National Physical Laboratory. As the method of maintaining units in these laboratories has not been changed since 1912, it is to be expected that these units will gradually drift apart and need adjustment from time to time. New methods of maintaining units are being studied and doubtless will be adopted as soon as their usefulness has been determined.

Maintenance of the Unit of Electromotive Force.—The unit of electromotive force is maintained in the national laboratories by means of cadmium cells with a saturated electrolyte. The Reichsanstalt and the Bureau of Standards use cells in which the electrolyte is neutral, whereas the National Physical Laboratory uses acid cells. There is usually a variation of several microvolts between the individual cells of a group which are constructed at the same time from the same materials. Cells constructed at different times from materials which have been purified by different methods may show differences in electromotive forces of 10 or even 20 parts in 1,000,000.

In 1910 the International Technical Committee, composed of physicists from England, France, Germany and the United States met at the Bureau of Standards to determine experimentally the value that should be assigned to the average neutral Weston cell (designated as the Weston normal cell). The value was determined in terms of the mercury ohm and the silver voltameter. The value of 1.0183 volts at 20° C was decided upon but this has been interpreted by all the national laboratories as 1.018300 volts at 20° C.

Beginning in 1911, the Bureau of Standards maintained its unit of electromotive force by means of a group of more than 40 cells, a number of which were made by the International Technical Committee. It was soon evident that many of the cells were changing by large amounts, so that in 1914 a readjustment was made, basing the unit on a group of cells which had been under observation since 1906 and which had been assigned values by the International Committee in 1910. There were about 20 cells in this group and a number of them are still retained in the primary group of the Bureau. The values of two of these cells which show the least change relative to the maintained unit are shown in the upper part of Figure 3.

In the lower part of Figure 3 are shown the changes which have occurred in the two cells which show the largest change of any now in the reference group. The maximum change, while in the reference group, is about 50 microvolts. Since 1914 the standard group has consisted of about 20 cells, the average value of which is assumed to remain constant.

The Reichsanstalt has used the same method of maintaining the volt as has the Bureau of Standards. It would appear that they were not as fortunate in the selection of cells as the Bureau of Standards since, following a new international determination of the values of cells by means of the silver voltameter in 1931, they changed the value assigned to their standard group by 80 parts in 1,000,000.

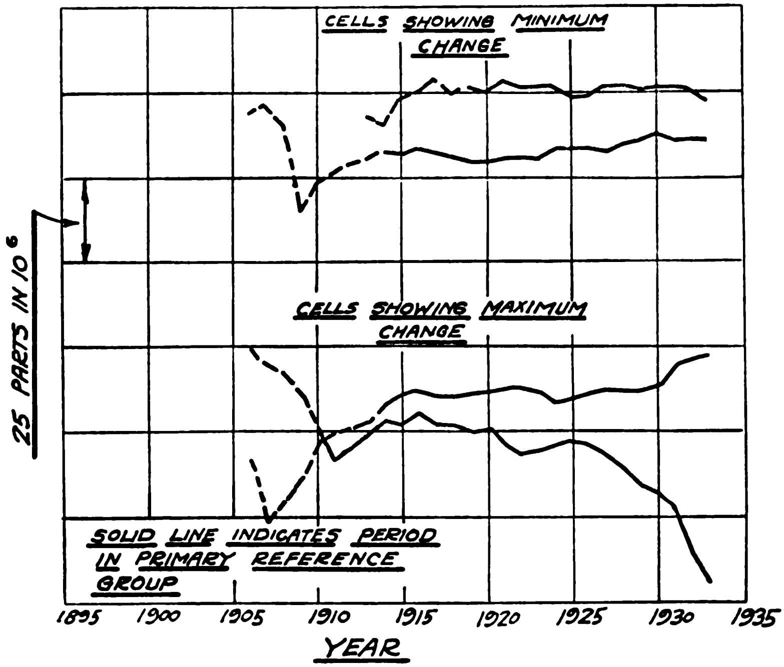

FIG. 3.—Changes in the electromotive force (relative to the maintained unit) of several cells now in the primary reference group of the Bureau of Standards.

The National Physical Laboratory also depends upon a group of thirty cells remaining constant, but the cells composing this group were not all made at the same time. Batches of new cells are made at intervals of a year or so, and the standard group consists of six cells from each of the last five batches. Whenever new cells are made, six are selected to replace the six oldest cells in the standard group. The values of the new cells are determined by comparing them with the standard group before the old cells are removed. Thus when these new cells replace the old ones in the group, the unit of electromotive force is not changed. By this procedure, the drift in the unit with time depends upon cells which are never more than five years old.

Between national laboratories, the intercomparison of standard cells is somewhat more difficult than for standard resistances. The difficulties of such an intercomparison and the differences which have existed between the units of the Bureau of Standards and the National Physical Laboratory are well shown by the results plotted in Figure 4.

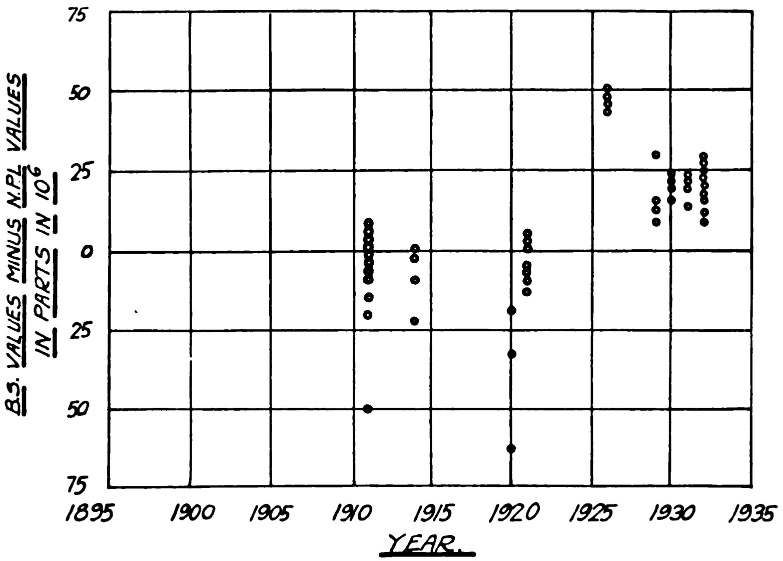

FIG. 4.—Difference between values of cells measured at the Bureau of Standards and National Physical Laboratory in different years.

In this diagram are shown the values for each individual cell used in recent comparisons between these laboratories. It is quite evident that the values obtained on three cells in 1920 have little significance, since the values are widely scattered and do not agree with those coming before or after. Likewise, the 1926 results, while agreeing among themselves, may not represent correctly the difference in the units of the two countries. It would appear that the units of the two countries were practically identical from 1911 to 1921, but since 1929 there has existed a fairly constant difference.

The results given demonstrate that laboratories giving especial attention to the maintenance of standard cells may have variations in the unit of electromotive force of several parts in 100,000 during a decade. Until the causes of these changes have been definitely determined, no laboratory can be certain that such changes will not occur in its own unit.

The results of the latest intercomparison made in the summer of 1932 show that a cell, which was assigned a value of 1.018300 volts at the Bureau of Standards (Weston normal cell), would be given a value of 1.018285 volts if measured at the Reichsanstalt, and a value of 1.018283 volts if measured at the National Physical Laboratory. The maximum difference between any two laboratories was 17 parts in 1,000,000. This close agreement is the result of adjustments which were made in 1931. With the present methods of maintaining the units, it is to be expected that this difference will gradually increase and that eventually another adjustment will become necessary.

THE REPRODUCIBLE STANDARDS

At the Paris Electrical Congress of 1881, a decision was reached to define electrical units in terms of reproducible standards, the constants to be agreed upon by the Congress after giving due consideration to the results of experiments for determining their absolute values. This method has been adopted by subsequent electrical congresses and conferences. The last establishment of the constants of the reproducible standards was made at the London Electrical Conference of 1908. The two standards for which constants were established are the mercury ohm (for establishing the unit of resistance) and the silver voltameter (for establishing the unit of current).

Mercury Ohm.—One of the latest determinations of the unit of resistance by the mercury ohm was that made at the Reichsanstalt[4] between 1920 and 1924. In this determination, ten different glass tubes were used for holding the mercury column. The maximum variation between the results of different tubes was 70 parts in 1,000,000 and the average variation was 20 parts in 1,000,000. It can be seen from the above that the determination of resistance by means of the mercury ohm is not particularly accurate.

The Silver Voltameter.—A series of international experiments with silver voltameters was made in 1931 as a means of adjusting to closer agreement the units of electromotive force of England, Germany and the

[4] Steinwehr, H. von, and Schulze, A. New determination of the international unit of electrical resistance. Ann. Physik (4), 87: 769-810 (1928).

United States.[5] Ten experimental determinations were made using six voltameters in each experiment, but the two voltameters from each national laboratory were treated as a single instrument in tabulating results. The maximum difference in the 30 results is over 300 parts in 1,000,000 and the average variation 60 parts in 1,000,000. These determinations were made under the disadvantageous conditions of an international series of experiments. It is probable that a determination at any one of the laboratories would not show quite so much variation.

RESULTS OF ABSOLUTE DETERMINATIONS

The result of an absolute determination of either resistance or current can be most readily expressed in terms of the units of the laboratory at which the determination is made. With satisfactory intercomparisons between the national laboratories, the results can be expressed in terms of the units of any laboratory. This is somewhat more definite than attempting to express the results in terms of the mercury ohm and the silver voltameter.

Researches on the absolute values of the electrical units are in progress in many of the national laboratories. The results of very few of these have as yet been published. However, provisional values were communicated to the Advisory Committee on Electricity which met in Paris in January, 1933. From these provisional values it appears that the most probable relations of the present units to the absolute ohm and absolute ampere are as follows:

1 B. S. International ohm $= 1.000460 \pm 20$ absolute ohms.
1 B. S. International ampere $= 0.999900 \pm 40$ absolute ampere.

From these values it follows that

1 B. S. International volt $= 1.000360$ absolute volts.

CONCLUSION

The electrical units were established in terms of the mechanical units, using the doctrine of the conservation of energy and assigning an arbitrary value (unity) to the permeability of a vacuum. They have been maintained by means of working standards and reproducible standards. Working standards show appreciable changes with time, so that their values must be occasionally redetermined either by means of reproducible standards or by re-establishing them in terms of the mechanical units by absolute electrical measurements. The accuracy with which the value of a working standard can be determined by reproducible standards may be less than the accuracy of determining it by absolute measurements.

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[5] Vinal, G. W. International comparison of electrical units. Bur. Standards J. Research 8: 729-749 (1932). (R. P. 448).

The Advisory Committee on Electricity of the International Committee of Weights and Measures has recommended that, in the future, the values of the working standards of the International Bureau of Weights and Measures and of the national laboratories shall be periodically redetermined on the absolute basis. If this recommendation is adopted, the reproducible standards (mercury ohm and silver voltameter) will be discarded. It is the expectation of the Advisory Committee that all national laboratories will adjust their units on January 1, 1937, to values decided upon by the International Committee. The Committee will base its decisions on the results of absolute measurements.

POSSIBLE EXTENSIONS OF THE EXISTING INTERNATIONAL SERIES OF ELECTRIC UNITS (OHM, VOLT, AMPERE, COULOMB, FARAD, HENRY, JOULE AND WATT) INTO A COMPLETE ABSOLUTE SYSTEM

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It is hoped to outline briefly in this paper, a part of the great opportunity which lies open before the Symbols, Units and Nomenclature (SUN) Committee of the International Union of Pure and Applied Physics (IPU) to advance the rational development of basic and applied physics, by securing international agreement on certain of those most useful scientific tools—symbols, units and nomenclature. In the particular field of electromagnetic units, the SUN Committee has opened an international discussion of the c.g.s. magnetic units, with a view to eliminating certain discordances in world magnetic literature, has circulated a questionnaire,[1] analysed replies to the same, and has held a meeting at Paris in July, 1932, for the discussion of the subject. In addition to following up this subject, the SUN Committee can be of great service to physics in many directions. In particular, it might be able ultimately to help bring about the extension of the existing series of practical electromagnetic units (ohm, volt, ampere, etc.) into a comprehensive international unit system serviceable for all branches of science. Suggestions are offered in this paper as to how such extension might be effected.

THE SUN COMMITTEE OF THE IPU

The SUN Committee was established at the Brussels meeting of the IPU in July, 1931, under the chairmanship of Sir Richard Glazebrook, F. R. S. and with Dr. E. Griffiths, at the National Physical Laboratory, Teddington, as Secretary. It is generally admitted that there has been much need for such an international committee in the past and there is likely to be even more need for it in the future. It is desirable to have international standardization of the literal and algebraic symbols used for designating the physical quantities which are in well established general use. It is also very desirable that the various units necessary for measurement in the many fields of physics should be adopted internationally and systematically. It would likewise be desirable, as time goes on, to have a glossary, approved by the IPU, of physical terms and their definitions.

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[1] International Union of Physics. Commission for Symbols, Units and Nomenclature. Electrical Units. Dec., 1931. 2 p.

It seems quite possible that if the accomplishments of the SUN Committee meet with success, the existence of the IPU would be amply justified by those accomplishments alone.

THE EMMU COMMITTEE OF THE IEC

The International Electrotechnical Commission (IEC) was inaugurated in 1904, at the International Electrical Congress in St. Louis, U. S. A. It was founded by Col. R. E. Crompton in 1906, with its secretariat at 28 Victoria St., London (Mr. C. LeMaistre, General Secretary). It deals mainly with the standardisation, rating and testing of machinery and apparatus employed in electrical engineering, the work being divided among 18 advisory committees. Advisory Committee No. 1 has dealt with electrical engineering nomenclature, units and symbols. Section B, of which the writer has been chairman, deals with Electric and Magnetic Magnitudes and Units (EMMU). The IEC is supported by nearly 20 countries and, since 1906, has held nineteen plenary meetings, distributed successively among 12 countries. The IEC also authorizes the holding of international electrical congresses, of which the latest —the eighth—was at Paris in 1932. The present and eighth President of the IEC is Dr. A. F. Enström of Sweden.

HISTORICAL OUTLINE OF THE PRACTICAL ELECTRICAL UNITS

The literature of physics shows that physical units have advanced along a tortuous and irregular path. It is only in recent years that unitology, or the science of physical units, may be said to have claimed recognition. Although units of weights and measures go back to the earliest historical records, yet they were evidently built up in haphazard fashion. Some followed a binary series (1, 2, 4, 8, etc.), others a sexigesimal series (1, 60, 360, 3600, etc.), and yet others in series of 12, 10, 20 or mixed numbers. It was not until the introduction of the French metric system, based on the decimal series (10^{-n}, ... 10^{-6}, 10^{-5}, 10^{-4},

10^{-3}, 10^{-2}, 10^{-1}, 1, 10, 10^2, 10^3, ... 10^n) about the year 1795,[2] that marked progress took place towards a system of unitology available both for science and for commerce.

Physicists began to employ the metric series of measures about 1820, especially in the direction of dynamics. Search was made for a comprehensive dynamical system of metric units. Until the beginning of the present century, it was customary to suppose that dynamics was the basic physical science, on which the unitology of all other branches should be constructed with reference to the fundamental units of length L, mass M and time T, thus forming a so-called "absolute system."

Gauss[3] published in 1833 his remarkable method and technique for measuring the earth's magnetic field in M. M. S. (millimeter-milligram-second) absolute units. The extension of the electric telegraph system about 1840 created a need for electric measures and units. In 1840, Wheatstone,[4] in England, appears to have first devised and constructed an adjustable resistance, employing as a unit one foot of copper wire weighing 100 grains (6.48 gm.). Owing to the lack of uniformity and low conductivity of copper wires used at that time, the value, in ohms, of this unit cannot be definitely stated.

Jacobi, in St. Petersburg, Russia, about 1850, proposed a unit of resistance in copper wire defined in foot-grains, but later as one meter of copper wire one millimeter in diameter.

Werner Siemens, in Germany, produced in 1860 his mercury unit: a prism of pure mercury one meter long and one sq. mm. in cross section at the temperature of 0° C, contained in a glass tube. This Siemens unit was a little less than one international ohm (about 0.94 ohm) and was the first approach to a definite and reproducible resistance unit.

Weber, at Leipzig, showed in 1851 how electromotive forces and resistances might be measured in absolute units. For this purpose he suggested the use of the tangent galvanometer.

In 1861, the B. A. (British Association for the Advancement of Science) adopted the proposal of two telegraph engineers—Latimer Clark and Charles Bright—to appoint a committee on "Standards of Electrical Resistance." This committee brought in reports until 1867. It adopted the M. G. S. (meter-gram-second) absolute magnetic system.[5] As the units of resistance and of electromotive force in that system were very small from an engineering standpoint, the committee proposed the adoption of 10^7 and 10^5 of these absolute units as the B. A. units of resistance and electromotive force, respectively, under the suggested names of the *ohm* and the *volt*. In this way the *ohm* came out close to the Siemens unit already in use, and the *volt* near to the electromotive force of a Daniell copper sulfate cell. The committee likewise suggested the name *farad* for a unit of capacitance, equal to 10^{-13} of a MGS unit, for the reason that a standard *farad* would be not far from the capacitance of a nautical mile of a common size of telegraph cable. Later, however, this standard was called a *microfarad,* and the *farad* was changed to 10^{-7} of a MGS unit,[5] in order to preserve the internal relation of these new units, and so that one *farad* might contain unit electric charge under a tension of one *volt*. It was proposed to call this unit charge or quantity the *weber,* i.e., the quantity of electricity passed through a voltaic circuit in one *second,* by the action of one *volt* through a resistance of one *ohm*. Thereafter, all the unit magnitudes established themselves in the series, starting from the arbitrary selection of 10^5 MGS units for the *volt* and 10^7 MGS units for the *ohm*.

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[2] French law of April 7, 1795. *See* A. E. Kennelly, Vestiges of primitive weights and measures persisting in metric-system Europe, 1926-1927. New York, Macmillan, 1928.

[3] Gauss, Karl Friedrich. Intensitas vis magneticae terrestris ad mensuram absolutam revocata . . . . Gottingen, 1832.

[4] Wheatstone, Charles. An account of several new instruments and processes for determining the constants of a voltaic current. Phil. Trans. 133: 303-382 (1843).

[5] Clark, Latimer, and Sabine, Robert. Electrical tables and formulae. Preface, 1871. 285 p.

The first B. A. Committee carried out its program [6] so far as to issue copies of the standard B. A. ohm in coils of platinum-silver wire and standard B. A. microfarad condensers of mica and tinfoil plate construction. Although voltaic cells were able to furnish rough standards of emf. (electromotive force), it was not until Latimer Clark [7] brought out his standard zinc-mercury cell in 1873, that a satisfactory reproducible standard of emf. (electromotive force) could be obtained. This was replaced in later years by the standard Weston zinc-cadmium cell [8] (1892), which has the advantage of a lower temperature coefficient of variation in emf.

The second B. A. Committee brought in its first report [9] in 1873. It decided in favor of the centimeter-gram-second system (CGS),[10] as against the first committee's choice of the MGS system, mainly for the reason that the CGS density of water, under proper specifications, is unity (1 gm. per cm.^3), whereas its MGS density is 10^{-6} (1 gm. per m.^3). The transition from MGS to CGS was not, however, effected without opposition. One member of the committee openly dissented, and insisted on having his name recorded as opposed to the change.

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[6] British Association Reports, 1861, 1863, 1864, 1865, 1867.

[7] Clark, Latimer. On a standard voltaic battery. Phil. Trans. 164: 1-14 (1874).

[8] Weston, E. Weston standard cell. Electrician (London) 30: 741 (1893).

[9] British Association, Committee Report, 1873.

[10] Kennelly, A. E. Historical outline of the electrical units. J. Eng. Education 19: 229-275 (1928).

Table 1 presents the series of nine practical units thus far internationally adopted.

Column I gives the serial number; column II, the quantity unitized; column III, the quantity dimensions, on the basis of L, M, T, and μ; column IV, the symbol or defining equation from a dimensional standpoint; column V, the name for the practical unit, as suggested by the first B. A. Committee; column VI, the magnitude of the unit in MGS units; column VII, the corresponding magnitude expressed in CGS units; column VIII, the unit name as internationally adopted; and column IX, the date of adoption. It will be observed that the practical unit of inductance was named the *quadrant* in 1889; but was renamed the *henry* in 1893. The unit of magnetic flux Φ in this series (No. 9) was adopted by the IEC at its Scandinavian meeting of 1930, under the provisional title of *pramaxwell,* the *maxwell* being the name of the CGS magnetic unit of magnetic flux (Φ) as adopted at Paris in 1900 and again at Oslo in 1930.

It will be seen from Table 1, that as soon as the *ohm* was fixed for convenience at the magnitude of 10^7 MGS magnetic units or 10^9 CGS magnetic units and likewise the *volt* at 10^5 MGS magnetic units or 10^8 CGS magnetic units, all the other seven practical units of the series become automatically fixed in their magnitudes, as shown, according to the principle of unity sequence. If the unit of length in a system is L (say 1 *meter*) and the unit of time is T (say 1 *second*), then the unit of velocity, according to unity sequence, will be $V=L/T$, or 1 *meter per second,* and not aL/T *meters per second,* where a is a numerical coefficient other then unity. If a system of units is not unity-sequenced, the incursion of numerical coefficients injects a perpetual burden on the memory and on numerical computation. It may not be possible to have a comprehensive system of units unity-sequenced throughout; but the principle should be followed as far as possible.

The unity-sequence relation of the nine practical units in Table 1 clearly involves a troublesome list of exponents in their relations to the corresponding units of the basic system. Thus, in column VI, the decimal exponents in reference to MGS units for the series, are five in all (-7, -2, 3, 5 and 7). Likewise in column VII, in reference to the CGS system, the number of exponents is also five (-9, -1, 7, 8 and 9). Extending the series, moreover, tends to increase the number of derivative exponents. According to the philosophy of the founders of the B. A. practical series, as laid down in the reports of the first B. A. Committee, it appears that the object of the series was to furnish definite standards for measurements, such as *ohm* coils and *microfarad* condensers, while computations were to be either all, or nearly all, in the

TABLE 1

SERIES OF PRACTICAL ELECTROMAGNETIC UNITS AND DATES OF THEIR ADOPTION

No.	Quantity	Dimensions				Symbol	B.A. Name[5] 1861-1867	Size of unit in		International name	Date
		L	M	T	μ			MGS	CGS		
I	II	III				IV	V	VI	VII	VIII	IX
1	Resistance	1	0	−1	1	R	*ohm*	10^7	10^9	*ohm*	1881
2	Electromotive force	$\frac{3}{2}$	$\frac{1}{2}$	−2	$\frac{1}{2}$	E	*volt*	10^5	10^8	*volt*	1881
3	Quantity	$\frac{1}{2}$	$\frac{1}{2}$	0	$-\frac{1}{2}$	$Q = ET/R$	*weber*	10^{-2}	10^{-1}	*coulomb*	1881
4	Current	$\frac{1}{2}$	$\frac{1}{2}$	−1	$-\frac{1}{2}$	$I = E/R$	*weber/sec*	10^{-2}	10^{-1}	*ampere*	1881
5	Capacitance	−1	0	2	−1	$C = Q/E$	*farad*	10^{-7}	10^{-9}	*farad*	1881
6	Energy	2	1	−2	0	$W = EQ$	......	10^3	10^7	*joule*	1889
7	Power	2	1	−3	0	$P = W/T$	......	10^3	10^7	*watt*	1889
8	Inductance	1	0	0	1	$\mathfrak{L} = \Phi/I$	......	10^7	10^9	*quadrant* *henry*	1889 1893
9	Magnetic flux	$\frac{3}{2}$	$\frac{1}{2}$	−1	$\frac{1}{2}$	$\Phi = W/I$	......	10^5	10^8	*pramaxwell*	1930

basic MGS system. Each working formula in the MGS system would call for the insertion of the proper decimal exponent when working from measurements employing B. A. units. The burden of inserting the proper decimal coefficients in the working formulas was, however, so considerable that very soon practical formulas were sought and obtained for keeping the computations entirely in the B. A. units, thus making recourse to the fundamental MGS system unnecessary. Curiously enough, it seems that neither the first B. A. Committee, nor the B. A. itself, ever officially adopted [5] the unit names *volt, ohm, farad* and *weber* (intentionally written *veber* at first, for English-language pronunciation); indeed the B. A. reports, until 1873, designate these practical units as B. A. units merely; but the names suggested by the Committee rapidly spread among technicians and were soon marked upon the standards themselves. By the year 1871, the names *ohm, volt* and *farad* had become the current terms of the electrical vocabulary and have continued to this day; while the *weber,* doing duty both for quantity and for current strength, persisted until replaced internationally by the *coulomb* and *ampere* respectively, in 1881. When the second B. A. Committee brought in its first report in 1873, recommending the change to the CGS system, it pointed out that the proper procedure should be to give names to the fundamental CGS units, with a standard set of prefixes and suffixes to designate exponent coefficients.[9, 11] If this excellent suggestion could have been carried into effect, we should all be employing the CGS system exclusively and the practical units, as a separate series, would not exist. Thus, if the name *ohm* had been given to the CGS magnetic unit of resistance, the practical unit and its standard that we now call the *ohm,* would be known as the *ohm-nine.* Similarly, the *volt* unit and standard would be known as the *volt-eight;* while the *microfarad* standard would be known as the *fifteenth-farad* condenser. This suggestion in 1873, came, however, some ten years too late. It was then hopeless to change the widely distributed nomenclature and established literature. No attempt at that date to change the term *ohm* to *ohm-nine* could have had much hope of success. The Second B. A. Committee's report of 1873 virtually admits the situation as hopeless for the three practical units, *ohm, volt* and *farad,* already in use, but indicated some hope for fastening new practical units on to the CGS system directly.

As time went on, the almost inevitable consequences of electrical nomenclature from 1863 to 1873 came into action all over the world. The two classical CGS systems (magnetic and electric) of the second B. A. Committee became the common bases of all branches of science;

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[11] Everett, Joseph D. Illustrations of CGS system of units. New York, Macmillan, 1891. Appendix, up to and including fourth edition.

but in applied electricity and even to a considerable extent in basic electricity, the practical series of units held sway. Electrical engineering text books used the practical units largely and sometimes exclusively. The practical series were, however, found inadequate for magnetics and also for theoretical work in electromagnetics.

The rapid advance of the dynamo-electric generator and motor in the period 1880-1890 brought great development in magnetics, both basic and applied. Magnetic units and unit names came into demand among practitioners. In those days, international electrical congresses were the only agencies through which new units or unit names could be secured. Attempts were made at the Paris Congress of 1889 to introduce a practical unit of magnetic flux (Φ) and also a practical unit of magnetic flux density (B), both as 10^8 CGS magnetic units. The Congress considered adopting the former, under the name *maxwell* and the latter under the name *weber,* but finally took no action.[12] In the then many existing terrestrial magnetic observatories, it was customary to use the terms "CGS Unit" for such magnetic units as were needed in their work, and there were many who considered that this practice should be sufficient for all magnetic purposes.

A second effort to secure magnetic units and unit names in the practical series was made at the Electrical Congress at Frankfort in 1891. Units for field intensity (H) and flux density (B) were discussed, with respective names of *gauss* and *weber,* but no action was taken.

The same question was brought before the International Electrical Congress of Chicago in 1893. The Congress passed a resolution that CGS units should be recommended for magnetic work, and that for the present no names should be assigned to them.

At the International Electrical Congress of Paris, in 1900, a proposition was made to adopt four names for the CGS magnetic units of magnetomotive force ($\mathscr{F}$), reluctance ($\mathscr{R}$), flux (Φ), and flux-density (B), under the respective titles of *gilbert, oersted, maxwell* and *gauss.* This involved a departure from the previously supported custom of assigning names of savants to practical series units only, in view of the Chicago Congress recommendation. The Congress adopted the names *maxwell* and *gauss* for the CGS units of magnetic flux (Φ) and magnetising force (H); although there was some accidental misunderstanding as to whether the *gauss* had not been assigned to flux density (B). This uncertainty gave rise to some confusion in subsequent magnetic literature.

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[12] Wolff, F. A. The so-called international electrical units. Proc. Intern. Elec. Congress, St. Louis, 1904, I: 148-169; J. Inst. Elec. Eng. 34: 190-228; 35: 3-42 (1905).

No international action was then taken on unit names or magnitudes until 1927, when a proposal was made at the Bellagio meeting of the IEC to transfer the name *maxwell* from the unit of flux (Φ) in the CGS system to that of flux (Φ) in the practical series (10^8 CGS magnetic units). This proposal led to the IEC action taken at Oslo in 1930, adopting the names *gilbert, oersted, maxwell* and *gauss* for the CGS magnetic units of magnetomotive force ($\mathscr{F}$), magnetic intensity (H), flux (Φ) and flux density (B), respectively, all based on the convention that the quantities represented by B and H are not identical; or in other words, that their ratio in a vacuum, the space permeability (μ_0), is not a simple numeric. These recommendations were endorsed by the IEC EMMU Committee at London in 1931, and by the SUN Committee of the IPU at Paris in 1932.

CLASSIFICATION OF UNIT SYSTEMS USED IN MODERN LITERATURE

During the half century which has elapsed since the *ohm, volt, coulomb, ampere* and *farad* were adopted at the Paris Congress of 1881, there has been an increase in the number of unit systems appearing in scientific literature. They appear in Table 2.

TABLE 2

Unit Systems Based on the Meter, Gram and Second

1. The CGS classical magnetic system of Maxwell.
2. The CGS classical electric or electrostatic system of Maxwell.
3. The CGS system of Gauss.
4. The CGS rationalised system of Heaviside-Lorentz.
5. The incomplete practical series of nine internationally adopted units.
6. The Maxwell QES practical system (quadrant, eleventh-gram, second).
7. The Giorgi MKS practical system (meter, kilogram, second).
8. The Dellinger-Bennett CGSS practical system (centimeter, gram-seven, second).

Numbers 1 and 2 in the above Table have been mutually helpful in establishing electromagnetic relations; but on the other hand, they have tended away from simplification, since either system alone would suffice for all purposes. Either could be dispensed with, if so desired.

Number 3 makes the space inductivity (ϵ_0) and space permeability (μ_0) both equal to unity, while making the magnetomotive force of a coil of NI current-turns equal to $4\pi NI/c$, where c is the light velocity. This simplifies considerably the algebraic expression of many physical relations.

Number 4 is a "rationalised system," i.e., is a system in which a unit pole emits unit magnetic flux and unit charge unit electric flux; also a coil of NI current-turns has a magnetomotive force of NI/c. Moreover, ϵ_0 and μ_0 are both taken as unity. This plan greatly simplifies many fundamental algebraic expressions, and is much used in modern basic physics.

Number 6 enables the practical series (number 5) to be extended into a complete absolute system. The unit of length (10^7 meters) is, however, so awkwardly great, that no serious attempt has been made to bring the QES system into practical use, to say nothing of the extremely small value of the unit of mass (10^{-11} gm.). Its discoverer Maxwell[13] does not seem to have regarded the system as fitted for practical service.

Giorgi,[14] in 1901, brought forward number 7 as a plan for extending number 5 into a complete comprehensive system. The plan was reviewed favorably by specialists in several countries; the only objection raised thus far against its broad features has been that its unit of density (1 kg. per cubic meter) is one thousand times less than the standard density of water. In addition, he proposed to rationalize the system by making the unit of magnetomotive force equal to the ampere-turn, and by taking the numerical value of space permeability (μ_0) as $4\pi \cdot 10^{-7}$ and that of space permittivity (ϵ_0) as $10^7/(4\pi c^2)$, or to three digits, 8.85×10^{-12}. In this way, no separate practical electric system would be required. Papers, but no books, have been published in this system.

Number 8 claims various authors, Dellinger,[15] Bennett,[16] Karapetoff Mie, and others.[16] It can accomplish the same results as number 7 for completing the practical series number 5 into a complete system. It employs the centimeter as length unit, and the gram-seven, or 10^7 grams (ten metric tons) as the mass unit. Like the Giorgi system, it could be adopted either unrationalized or rationalized; but in the publications that have used it, this system has been rationalized, with space permeability (μ_0) taken as $4\pi \cdot 10^{-9}$, and space permittivity (ϵ_0) as $10^9/(4\pi c^2)$, or to three digits, 8.85×10^{-14}. At least one book[17] has been issued in this system.

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[13] Maxwell, J. Clerk. A treatise on electricity and magnetism, 1881.

[14] Giorgi, G. Unita razionali di elettromagnetismo. Atti assoc. elettrotecn. 5: 402-418 (1901). Proposals concerning electrical and physical units. Proc. Intern. Elec. Congress, St. Louis, 1904, I:136-141; J. Inst. Elec. Eng. 34:181-185 (1905).

[15] Dellinger, J. H. International system of electrical and magnetic units. Bureau of Standards, Sci. Paper 292. 1916. 33 p.

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CONDITIONS FOR POSSIBLE EXTENSION OF PRACTICAL SERIES INTO A SYSTEM

If the existing practical series of nine units shown in Table 1, could be extended into a comprehensive system that was internationally acceptable, the benefit gained would be that only this system would have to be taught and learned in order to meet the needs of all classes of electrical workers, and indeed of scientific workers generally. Out of the eight systems in Table 2, only one system—No. 5 extended—would be needed.

The conditions limiting such an extension are:

(1) The units of length and mass to be used must be decimally based on the meter and gram, while the time unit must be the mean solar second.

(2) Each and all of the nine units in Table 1 must be retained as constituent units in the completed system.

Suggestions have been made that a better complete system could be attained if some of the existing units of the series were altered decimally in magnitude. Considering, however, the widespread use of these units, and the great international effort that was required to arrive at them, it does not seem likely that consent could be obtained for their alteration.

From an examination of Table 1, it will be seen that starting with the two arbitrarily chosen units, *ohm* and *volt,* belonging basically to both the MGS and CGS systems, the unity-sequence principle would prescribe all the other seven members of the series, including the magnitudes of both the *joule* and the *watt.* In order to complete the series comprehensively, and with reference to other branches of science, the *joule* and *watt* must also be appropriate dynamical units. It was pointed out by Ascoli [18] in 1904 that, in order to have the *joule* a proper unit of dynamical energy in any dynamical system of unit length $L=10^l$ *cm.* and of unit mass $M=10^m$ *grams,* keeping T at 1 *second,* we must have $MV^2=10^{2l}\times10^m=1$ *joule* $=10^7$ *ergs.* Thus neglecting T as invariable, we must have $2l+m=7$, in order that the unit of dynamical energy in that system may be 1 *joule.* It is easily shown that if the L and M units satisfy the *joule,* they will also satisfy the *watt* as unit of activity or power, considered dynamically. Table 3 presents ten possible pairs of length and mass units, which with the *second,* will satisfy the dynamical requirements of the *joule* and *watt,* in addition to the relations between the nine practical units of Table 1.

In Table 3, number 1 indicates the QES system of Maxwell, with $L=10^9$ cm. and $M=10^{-11}$ gm. It will be observed that $2\times9-11=7$.

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[18] Ascoli, M. On the systems of electrical units. Proc. Intern. Elec. Congress, St. Louis, 1904, I:130-135; J. Inst. Elec. Eng. 34:176-180 (1905).

The only other cases worthy of note are numbers 8 and 10, the MKS and CGSS systems, respectively. The table could, of course, be extended upwards or downwards indefinitely; but apparently without any other useful cases presenting themselves. The last four columns show the numerical values of μ_0 and ϵ_0 in each system, according as it is rationalized or unrationalized. It will be seen that the QES system is the only one in which the unrationalized value of space permeability (μ_0) is unity. In all of the ten systems, whether rationalized or not, the product $\epsilon_0\mu_0$ is seen to be $1/c^2$.

The *meter* and *kilogram* are better fitted for selection as basic dynamic units in a comprehensive system than the *centimeter* and the *gram-seven*. It is undesirable that basic units should possess a prefix, since a prefix always suggests a secondary relation to the basic unit from which it is derived. In this respect the *meter* is quite satisfactory, but the *kilogram* is open to criticism. It has been suggested, however, that for dealing with the internal relations of the MKS system, the word kilogram might be abbreviated either to *kram* or *kog*. It happens that the international *meter* and *kilogram* are the two actual standards preserved by the International Committee of Weights and Measures at Sèvres.

TABLE 3

TEN OF THE POSSIBLE DYNAMIC SYSTEMS SATISFIED BY THE JOULE AND WATT

No.	Unit of length cm.	Unit of mass gm.	System	Numerical value of μ_0		Numerical value of ϵ_0	
				Rat.	Unrat.	Rat.	Unrat.
1	$10^9 = 1$ quad.	10^{-11}	QES	4π	1	$1/4\pi c^2$	$1/c^2$
2	10^8	10^{-9}	—	$4\pi \times 10^{-1}$	10^{-1}	$10/4\pi c^2$	$10/c^2$
3	10^7	10^{-7}	—	$4\pi \times 10^{-2}$	10^{-2}	$10^2/4\pi c^2$	$10^2/c^2$
4	10^6	10^{-5}	—	$4\pi \times 10^{-3}$	10^{-3}	$10^3/4\pi c^2$	$10^3/c^2$
5	$10^5 = 1$ km	$10^{-3} = 1$ mg	—	$4\pi \times 10^{-4}$	10^{-4}	$10^4/4\pi c^2$	$10^4/c^2$
6	$10^4 = 1$ hm	$10^{-1} = 1$ dg	—	$4\pi \times 10^{-5}$	10^{-5}	$10^5/4\pi c^2$	$10^5/c^2$
7	$10^3 = 1$ dkm	10 gm.	—	$4\pi \times 10^{-6}$	10^{-6}	$10^6/4\pi c^2$	$10^6/c^2$
8	$10^2 = 1$ m	$10^3 = 1$ kg	MKS	$4\pi \times 10^{-7}$	10^{-7}	$10^7/4\pi c^2$	$10^7/c^2$
9	$10 = 1$ dm	10^5	—	$4\pi \times 10^{-8}$	10^{-8}	$10^8/4\pi c^2$	$10^8/c^2$
10	$1 = 1$ cm	10^7	CGSS	$4\pi \times 10^{-9}$	10^{-9}	$10^9/4\pi c^2$	$10^9/c^2$

In order to assign logically the units of L and M which are to be included in the practical system, it would suffice to adopt officially some practical gradient, intensity or voluminal unit. Thus, if the IPU and IEC were to adopt the *volt-per-meter* in contradistinction to the *volt-per-cm.* for electric gradient; or the *ampere-per-m.*^{2} instead of the *ampere-per-cm.*^{2} for practical current density; or the *joule-per-m.*^{3} instead of the *joule-per-cm.*^{3}, as the practical unit of volume energy, the unit of M would have to be the *kilogram* instead of the *gram-seven*. No such linear, superficial or voluminal unit has yet been adopted internationally, and any one such unit would, logically speaking, determine which system out of the ten offered in Table 3 should be owned thereafter by the practical series of Table 1. There are some, however, who do not grant this proposition. They point to such firmly fixed but unorthodox practical units as the *kilowatt-hour,* and they claim that there is no inconsistency in using the units *ampere-per-cm.^{2}*, *amperes-per-mm.^{2}*, *amperes-per-m.^{2}*, etc., according to convenience. The writer submits, however, that it is the duty of science to be systematic, and that, in any one field of science, each measurable quantity can properly have one and only one unit. One has only to contemplate the confusion that might follow if scientific unitology should assign a multiplicity of units for one and the same measurable quantity. As for the *kilowatt-hour,* it is everywhere recognised as a useful industrial unit of energy, but industry is not the recognised source of fundamental scientific units.

QUESTION OF RATIONALIZATION OF THE PRACTICAL SYSTEM

Another question which has to be decided before the practical system can be finally adopted is whether it is to be "subrationalized." It was Heaviside who, about 1870, pointed out the theoretical and practical advantages of what he denominated as a "rationalized" system of units. For present purposes, we may define a rationalized system as one in which unit electric charge emits unit electric flux, and a unit magnetic pole, unit magnetic flux. In both the electric and magnetic classical CGS systems, unit charge emits 4π units of electric flux and a unit pole, 4π *maxwells.* Most unitologists agree that if we could build up the CGS systems afresh and expunge all existing CGS literature, it would be desirable to do so on a rationalized basis; but that, in view of the widespread use of CGS literature and the great benefit derived from it in the past, it is undesirable to change the classical CGS systems today. Heaviside pleaded for the rationalization of both CGS and practical units. The method he proposed for doing this, however, involved changing the sizes of the units, and therefore altering the calibration of all electrical instruments. It was therefore unacceptable. Since that time, however, it has been shown by several writers that it is possible to secure the benefits of rationalization without altering the sizes of the existing units, by injecting the constant 4π into the accepted values of the space constants, ϵ_0 and μ_0, as is indicated in the last four columns of Table 3. This procedure has been called "subrationalization," to distinguish it from the Heaviside plan.

All of the nine practical units in Table 1 are neutral. They might belong either to a rationalized or to an unrationalized system. If, however, a practical unit were adopted for any of the quantities, magnetomotive force ($\mathscr{F}$), permeability (μ), permittivity (ϵ) or reluctance ($\mathscr{R}$), it would follow that these must either be such as to make the resulting system rationalized or unrationalized, whatever units of length or mass may be decided upon.

Table 4 indicates some of the changes in working formulas effected by subrationalization in the practical series:

TABLE 4

Partial List of Working Formulas Affected by Subrationalizing. Practical System

No.	Quantity of formula	Formula	
		Rat.	Unrat.
1	Magnetomotive force ($\mathfrak{F}$) of a coil of NI *ampere-turns*	NI	$4\pi NI$
2	Magnetic flux (Φ) from pole of m units (*pramaxwells*)	$\Phi = m$	$\Phi = 4\pi m$
3	Work done by coil of $\mathfrak{F}$ linking with flux Φ (*joules*)	$W = \mathfrak{F}\Phi$	$W = \mathfrak{F}\Phi/4\pi$
4	Work in carrying pole m around current I (*joules*)	$W = mI$	$W = 4\pi mI$
5	Tension between polar surfaces per unit area (no name)	$f = H.B./2$	$f = H.B./8\pi$
6	Magnetic volume energy of magnetic field (*joules/m.*^{3})	$w = B^2/2\mu_0$	$w = B^2/8\pi\mu_0$
7	Hysteretic volume energy per Ewing cycle (*joule/m.*^{3})	$w = \int H.\,dB$	$w = \frac{1}{4}\pi \int H.dB$
8	Electric flux (Φ_e) from a charge q (no name)	$\Phi_e = q$	$\Phi_e = 4\pi q$
9	Poynting's law of power per m.^{2} (*watts/m.*^{2})	$p = F.H$	$p = F.H/4\pi$
10	Elastance of plate condenser separated d m (*daraf*)	$S = A.d/\epsilon$	$S = A.4\pi d/\epsilon$
11	Elastance of spherical condenser (*darafs*)	$S = ({}^1/r_1 - {}^1/r_2)/4\pi\epsilon$	$S = ({}^1/r_1 - {}^1/r_2)/\epsilon$
12	Value of space permeability (μ_0)....	$4\pi \times 10^{-7}$	10^{-7}
13	Value of space permittivity (ϵ_0)....	$10^7/4\pi c^2$	$10^7/c^2$

Although the advantages of rationalization are very distinct, yet there is one disadvantage, namely, the divergence thereby effected between the classical CGS systems and the practical system. On the other hand, system 4 in Table 2, i.e., the Heaviside-Lorentz system, is rationalized, and a large part of modern eletromagnetic theory is carried on today in the Heaviside-Lorentz system, on account of the greater convenience and simplicity which it offers. Much difference of opinion seems to exist among both physicists and technicians over the question of rationalization, not only in different countries, but also within one and the same country. Unless nearly unanimous agreement can be reached one way or the other, it may be desirable to leave the question open for the present and recognise the existence of both parties in carrying on the practical system; just as there are already both parties at work, side by side, in carrying on the CGS systems. Rationalists should not be forced to use classical practical units, nor classicists to use subrationalized practical units.

LIST OF UNITS IN MKS SYSTEM COMPRISING ALL OF THE PRACTICAL UNIT SERIES

Table 5 presents a list of the principal mechanical, thermal, electric and magnetic units, making a complete and comprehensive MKS system out of the series of the nine practical units detailed in Table 1. Column I gives the number of the unit; column II, the quantity unitised; and column III a commonly used symbol for the same; the CGS magnetic unit is referred to in column IV, and the corresponding MKS unit in column V. The CGS electric units are omitted in column IV as unnecessary, since all the practical units, existing or proposed, are limited to the magnetic system. Columns VI and VII express the numerical relations between the MKS units and the corresponding CGS units. Column VIII gives the equivalent units in the CGSS system, with their numerical relations to the CGS in columns IX and X. None of the units appearing in Table 5 are affected by the question of rationalization.

Table 6 presents the series of practical electric and magnetic units for the MKS system only, with reference to rationalization or nonrationalization.

None of the units in Table 5 are affected by rationalization. In Table VI, there are four electric and ten magnetic units that are affected. The affected electric units are those that introduce space permittivity (ϵ_0) or its reciprocal, the space elastivity (s_0). Rationalization increases the first four magnetic units 4π times and reduces the next six 4π times, while it leaves the last five unaffected.

CONCLUSIONS

(1) The nine practical units of Table 1 form a unity-sequence magnetic series, i.e., their mutually defining equations exclude all non-unitary numerical coefficients. If the series were extended into a complete absolute system, without introducing a parallel electric system, it would simplify computations and theory, by rendering resort to the fundamental CGS electric and magnetic systems unnecessary.

(2) There are only three sets of dynamical units in *L, M* and *T* worth considering to complete the practical series into a complete system, namely, the QES, the MKS and the CGSS of Table 3. Only the MKS

TABLE 5

Comparison of MKS and CGSS Series, with Reference to the Classical CGS Mag. U.

No.	Quantity	Symbol	CGSU	MKSU Giorgi or Definitive	CGSU in 1 MKSU	MKSU in 1 CGSU	CGSSU Dellinger-Bennett	CGSU in 1 CGSSU	CGSSU in 1 CGSU
I	II	III	IV	V	VI	VII	VIII	IX	X
	MECHANICS								
1	Length	L	cm.	meter	10^2	10^{-2}	cm.	1	1
2	Mass	M	gm.	kilogram	10^3	10^{-3}	10^7 gm. = gm.-7	10^7	10^{-7}
3	Time	T	sec.	second	1	1	second	1	1
4	Area	A	cm.^{2}	m.^{2}	10^4	10^{-4}	cm.^{2}	1	1
5	Volume	V	cm.^{3}	m.^{3}	10^6	10^{-6}	cm.^{3}	1	1
6	Density	δ	gm./cm.^{3}	kg./m.^{3}	10^{-3}	10^3	gm.-7/cm.^{3}	10^7	10^{-7}
7	Velocity	v	cm./sec.	m./sec.	10^2	10^{-2}	cm./sec.	1	1
8	Acceleration	a	cm./sec.^{2}	m./sec.^{2}	10^2	10^{-2}	cm./sec.^{2}	1	1
9	Force	f	dyne	joule/m.	10^5	10^{-5}	dyne-7	10^7	10^{-7}
10	Pressure	p	dyne/cm.^{2}	dyne-5/m.^{2}	10	10^{-1}	dyne/cm.^{2}	10^7	10^{-7}
11	Torque	q	dyne ⊥ cm.	dyne-5 ⊥ m.^{2}	10^7	10^{-7}	dyne-7 ⊥ cm.	10^7	10^{-7}
12	Moment of Inertia	J	gm.-cm.^{2}	kg.-m.^{2}	10^7	10^{-7}	gm.-7-cm.^{2}	10^7	10^{-7}
	ENERGY								
13	Work and energy	W	erg	joule	10^7	10^{-7}	joule	10^7	10^{-7}
14	Action	α	erg-sec.	joule-sec.	10^7	10^{-7}	joule-sec.	10^7	10^{-7}
15	Volume energy	w	erg/cm.^{3}	joule/m.^{3}	10	10^{-1}	joule/cm.^{3}	10^7	10^{-7}
16	Power	P	erg/sec.	watt	10^7	10^{-7}	watt	10^7	10^{-7}
	THERMAL								
17	Heat	H	gm.-cal.	kg.-cal.	10^3	10^{-3}	gm.-7-cal.	10^7	10^{-7}
18	Temperature	t	deg. C.	deg. C.	1	1	deg. C.	1	1
	LUMINOUS								
19	Flux	F	lumen	lumen	1	1	lumen	1	1
20	Illumination	E	phot	lux	10^{-4}	10^4	phot	1	1
21	Intensity	I	candle	candle	1	1	candle	1	1
22	Brightness	B	candle/cm.^{2}	candle/m.^{2}	10^{-4}	10^4	candle/cm.^{2}	1	1
23	Focal power	—	cm.$^{-1}$	diopter	10^{-2}	10^2	cm.$^{-1}$	1	1

TABLE 6

ELECTRIC AND MAGNETIC UNITS IN MKS SYSTEM, RATIONALIZED AND UNRATIONALIZED

No.	Quantity	Symbol	CGS magnetic unit	MKS unit rat. (Giorgi)	CGSU in 1 MKSU	MKSU in 1 CGSU	MKS unit unrat.	CGSU in 1 MKSU	MKSU in 1 CGSU
I	II	III	IV	V	VI	VII	VIII	IX	X
	ELECTRIC								
1	Resistance	R	abohm	ohm	10^9	10^{-9}	ohm	10^9	10^{-9}
2	Resistivity	ρ	abohm-cm.	ohm-meter	10^{11}	10^{-11}	ohm-meter	10^{11}	10^{-11}
3	Current	I	abampere	ampere	10^{-1}	10	ampere	10^{-1}	10
4	Current density	I	abamp./cm.^{2}	amp./m.^{2}	10^{-5}	10^5	amp./m.^{2}	10^{-5}	10^5
5	Conductance	G	abmho	mho	10^{-9}	10^9	mho	10^{-9}	10^9
6	Conductivity	γ	abmho/cm.	mho/meter	10^{-11}	10^{11}	mho/meter	10^{-11}	10^{11}
7	Quantity	Q	abcoulomb	coulomb	10^{-1}	10	coulomb	10^{-1}	10
8	Displacement	q	abcoul./cm.^{2}	coul./m.^{2}	10^{-5}	10^5	coul./m.^{2}	10^{-5}	10^5
9	Capacitance	C	abfarad	farad	10^{-9}	10^9	farad	10^{-9}	10^9
10	EMF	E	abvolt	volt	10^8	10^{-8}	volt	10^8	10^{-8}
11	Elastance	S	abdaraf	daraf	10^9	10^{-9}	daraf	10^9	10^{-9}
12	El. Intensity	F	abv./cm.	volt/m.	10^6	10^{-6}	volt/m.	10^6	10^{-6}
13	El. Flux	Ψ	—	coulomb	$4\pi c^2/10^5$	$10^5/4\pi c^2$	—	$c^2/10^5$	$10^5/c^2$
14	El. Flux density	D	—	coul./m.^{2}	$4\pi c^2/10$	$10 \cdot 4\pi c^2$	—	$c^2/10$	$10/c^2$
15	Permittivity	ϵ_0	—	farad/m.	$4\pi c^2 \cdot 10^{-7}$	$10^7/4\pi c^2$	—	$10^{-7}c^2$	$10^7/c^2$
16	Elastivity	s_0	—	daraf-m.	$10^7/4\pi c^2$	$10^{-7} \cdot 4\pi c^2$	—	$10^7/c^2$	$10^{-7}c^2$
	MAGNETIC								
17	MMF	$\mathfrak{F}$	gilbert	amp-turn	$4\pi/10$	$10/4\pi$	pragilbert	10^{-1}	10
18	Magnetising Force	H	oersted	ampturn/m.	$4\pi/10^3$	$10^3/4\pi$	praoersted	10^{-3}	10^3
19	Reluctance	$\mathfrak{R}$	—	—	$4\pi 10^{-9}$	$10^9/4\pi$	—	10^{-9}	10^9
20	Space reluctivity	ν_0	cm/abh.	m./henry	$4\pi 10^{-7}$	$10^7/4\pi$	—	10^{-7}	10^7
21	Space permeability	μ_0	abh./cm.	henry/m.	$10^7/4\pi$	$4\pi/10^7$	—	10^7	10^{-7}
22	Permeance	$\mathfrak{P}$	—	—	$10^8/4\pi$	$4\pi/10^8$	—	10^9	10^{-9}
23	Magnetic pole	m	pole	pramaxwell	$10^8/4\pi$	$4\pi/10^8$	—	10^8	10^{-8}
24	Mag. moment	M	pole-cm.	pram.-m.	$10^{10}/4\pi$	$4\pi/10^{10}$	—	10^{10}	10^{-10}
25	Magnetization	I	pole/cm.^{2}	pram./m.^{2}	$10^4/4\pi$	$4\pi/10^4$	—	10^4	10^{-4}

TABLE 6

ELECTRIC AND MAGNETIC UNITS IN MKS SYSTEM, RATIONALIZED AND UNRATIONALIZED—*Continued*

No.	Quantity	Sym-bol	CGS magnetic unit	MKS unit rat. (Giorgi)	CGSU in 1 MKSU	MKSU in 1 CGSU	MKS unit unrat.	CGSU in 1 MKSU	MKSU in 1 CGSU
I	II	III	IV	V	VI	VII	VIII	IX	X
26	Magnetic flux	Φ	maxwell abvolt-sec.	pramaxwell volt-sec.	10^8	10^{-8}	pramaxwell volt-sec.	10^8	10^{-8}
27	Flux density	B	gauss	pram./m.^{2}	10^4	10^{-4}	pram./m.^{2}	10^4	10^{-4}
28	Inductance	$\mathfrak{L}$	abhenry	henry	10^9	10^{-9}	henry	10^9	10^{-9}
29	Mag. energy	W	erg	joule	10^7	10^{-7}	joule	10^7	10^{-7}
30	Volume energy	w	erg/cm.^{3}	joule/m.^{3}	10	10^{-1}	joule/m.^{3}	10	10^{-1}

Expression of numerical factors to five digits:
$4\pi = 12.566$; $1/4\pi = 0.079577$; $4\pi/10^7 = 1.2566 \times 10^{-6}$; $10^7/4\pi = 7.9577 \times 10^5$; $4\pi c^2 = 1.1294.10^{18}$ m^2/sec.^{2}; $1/4\pi c^2 = 8.8540 \times 10^{-19}$ sec.^{2}/m^2.

and the CGSS sets have any support. The CGSS set has the disadvantage that neither the *centimeter* nor the *gram-seven* are basic units, free from prefixes and suffixes. Moreover, the *gram-seven* (10 metric tons) is of awkwardly large size. On the other hand, the *meter* and the *kilogram* of the MKS system are the fundamental standards of the international metric system, as preserved at Sèvres. The *kilogram* is not basic, being affected with the prefix *kilo;* but in the use of the MKS system, this name might be reduced to one syllable, without destroying its relation to the *gram*. It is therefore claimed that the MKS system is preferable to the CGSS system for general adoption. In neither system is the density of water unity under standard specifications, but this is probably not a fatal defect, in view of our tables of specific gravities, which would remain unaffected in either case.

(3) If the unity-sequence definition of the practical unit of magnetomotive force is to be retained, that unit should be the *ampere-turn* and not the *pragilbert* of the 4π-th part of an *ampere-turn*. This would mean subrationalizing the practical series extension, without altering any unit thus far adopted. The advantage of the rationalizing would be to simplify a number of working formulae and to simplify much of the basic reasoning. A disadvantage would be that the practical system would, in this particular, be drawn out of parallelism with the classical CGS magnetic system, although it would be brought into closer relations with the Gaussian and Heaviside-Lorentz CGS systems, which are in considerable international use. In view, however, of the great differences of opinion over this rationalization question in almost all countries, it would seem desirable not to press for a decision upon it at present, but to recognize that both plans are in use. After a sufficient time may have elapsed to gain widespread experience as to the relative advantages of the two plans, an international agreement upon one of them might be more easily reached. In the meantime, it would only be necessary for each writer to indicate clearly which plan he followed.

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THE NATIONAL ACADEMY OF SCIENCES
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BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL

June, 1934 Number 94

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FELLOWSHIPS AND SCHOLARSHIPS FOR ADVANCED WORK IN SCIENCE AND TECHNOLOGY

THIRD EDITION

COMPILED BY
CALLIE HULL AND CLARENCE J. WEST
for
Research Information Service
National Research Council

STANFORD LIBRARY

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
OF
THE NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.
1934

461075

DESCRIPTIVE LIST OF FELLOWSHIPS BY INSTITUTIONS

AGNES SCOTT COLLEGE, Decatur, Ga.

Harrold (Quenelle) Fellowship. Founded by Miss Quenelle Harrold, 1926. Awarded to a senior of this College, or an alumna of not more than three years standing. Available for graduate study in any field, the graduate school to be approved by the Academic Council of the College. Stipend, interest on $10,000. Applications should be filed by January 1st with the Registrar.

AKRON, UNIVERSITY OF, Akron, Ohio.

Firestone Fellowship in Rubber Chemistry. Founded by the Firestone Tire and Rubber Company, 1920. Open to men with a B. S. degree. Available in this University for research on rubber. Stipend, $750 a year; nine hours per week required in laboratory supervision. Application should be filed by April 1st with Professor Walter A. Cook, University of Akron. Special application form furnished.

ALABAMA, UNIVERSITY OF, University, Ala.

Assistantships and Fellowships. A large number of these (between ten and fifteen) are assigned annually to graduate students in the School of Chemistry, and a few to undergraduates. A certain amount of investigative work is required of the graduate students to whom these are awarded. Stipend, $100 to $200 a year.

Graduate Industrial Fellowship in Ceramics. Founded 1930. Open to men and women with the A. B. or B. S. degree. Stipend, $600 a year. Applications should be filed with Professor of Ceramics.

Graduate Industrial Fellowships in Chemistry. Founded 1925. Open to men with the A. B. or B. S. degree, for study in this University. Stipend, $500 to $750 a year. Applications should be filed by April 1st with Dean of the School of Chemistry.

Ramsay (Robert) Fellowship in Chemistry. Founded 1926, by Erskine Ramsay. Open to men with the baccalaureate degree, for study in the University of Alabama. Stipend, $500 to $750 a year. Applications should be filed by April 1st with Dean of the School of Chemistry.

U. S. Bureau of Mines Fellowships. Four. Stipend, $675 for nine months, September to May. Applications should be filed with the Registrar.

ALABAMA POLYTECHNIC INSTITUTE, Birmingham, Ala.

See Du Pont de Nemours and Company, E. I.

ALFRED UNIVERSITY, Alfred, N. Y.

War Memorial Graduate Scholarship. Founded by subscriptions, 1920. Open to men and women who are graduates of this College or the New York State College of Ceramics. Available in any American or foreign university for general scientific study. Stipend, $300 to $350 a year. Applications should be filed by June 30th with J. Nelson Norwood, Alfred, N. Y.

ALPHA OMICRON PI, Central Office, Box 262, State College, Pa.

Alpha Omicron Pi Fellowship for Graduate Study. Founded 1923. Open to any women graduate student. Available in any American or foreign university for general study in scientific or other fields. Stipend, $1000 a year. Awarded in alternate years by the Committee on Fellowship Awards of the American Association of University Women and subject to the rules governing graduate fellowships administered by that Committee.

Alpha Omicron Pi Fellowship in Memory of Ruth Capen Farmer. Founded 1923. Open to any woman graduate of an approved college or university who is a member of Alpha Omicron Pi. Available in any American or foreign university for general study in scientific or other fields. Stipend, $750 a year. Awarded only in alternate years when following fellowship is not offered. Applications should be filed by March 1st with Miss Octavia Chapin, 102 Summer Street, Medford, Mass. Special application form furnished.

Alpha Omicron Pi Fellowship in Memory of Lillian MacQuillin McCausland. Founded 1931. Open to any woman graduate of an approved college or university who is a member of Alpha Omicron Pi. Available in any American or foreign university for general study in scientific or other fields. Stipend, $750 a year. Awarded only in alternate years when preceding fellowship is not offered. Applications should be filed by March 1st with Miss Octavia Chapin, 102 Summer Street, Medford, Mass. Special form furnished.

AMERICAN ASSOCIATION OF UNIVERSITY WOMEN, 1634 Eye St., N. W., Washington, D. C.

Applications and recommendations for these fellowships must be filed not later than January 1st. None can be accepted after that date. Address: Agnes L. Rogers, Chairman of the Committee on Fellowships, A. A. U. W., Bryn Mawr College, Bryn Mawr, Pa.

Alpha Omicron Pi Fellowship. Awarded biennially. Founded 1933, by Alpha Omicron Pi Sorority. Open to women with degree in arts, science or literature who show promise of distinction. Not restricted to any one subject. Stipend, $1000 a year. Application should be filed by December 1st with Secretary, Committee on Fellowship Awards, 1634 Eye St., N. W., Washington, D. C.

American Association of University Women International Fellowship. Founded by A. A. U. W., 1923. Open to all members of associations or federations of university women forming branches of the International Federation. Holder must carry on a year's research in some country other than her own. Stipend, $1500 a year.

Atkinson (Dorothy Bridgman) Fellowship. Founded by the Northwest Central Section of the A. A. U. W., 1929. Open to women who, in addition to having a bachelor's degree, have completed at least one year of graduate study and give promise of distinction. The field of study is limited to the arts, science and literature. Though it is available to women from every section of the country, all qualifications being equal, preference will be given to a candidate from the Northwest Central Section. Stipend, $1500 a year.

Berliner (Sarah) Research Fellowship. Founded by the Sarah Berliner Research and Lecture Fellowship for Women Fund Corporation, 1914. During the year 1928 the money was turned over to the A. A. U. W., to be held as a trust fund. Open to American women holding the degree of Ph. D. or D. Sc. or having an equivalent preparation. Available for research in physics, chemistry or biology. This fellowship is in effect two fellowships, of which one or the other (but not both) will be awarded each year: 1. A fellowship of $1200 for research only. 2. A docentship of $1500, the holder of which shall have arranged to continue research with the giving of one or more courses of lectures in the university at which she proposes to reside.

Brackett (Anna C.) Memorial Fellowship. Founded by A. A. U. W., 1912. Offered in alternate years by the A. A. U. W., as trustee of the memorial fund given by the Anna C. Brackett Association. Open to women who have degree in arts, science or literature, who intend to make teaching their profession. In general, preference is given to those applicants who have had successful experience in teaching and in addition have completed at least two years of graduate study. Stipend, $1000 a year.

Fellowship Crusade International Fellowship. An international fellowship to enable the holder to carry on a year's research work in science in some country other than her own. The fellowship is available for work in mathematics, physics, chemistry, geology, experimental psychology and biological sciences (including physiology and pathology). It is open to members of Associations or Federations forming branches of the International Federation of University Women. Stipend, $1500.

Fellowship Crusade National Fellowship. Founded 1929; first awarded in 1934. Open to American women for graduate study or research. Place of study undesignated. Stipend, $1500 a year. Applications should be filed by December 1st with Secretary of Committee on Fellowship Award, 1634 Eye St., N. W., Washington, D. C., on special form furnished. The million dollar fellowship fund is being raised by units. This first award is from the accrued interest on all payments to the fund. As soon as units are completed the fellowship will carry the name designated by the unit.

Latin-American Fellowship. Founded by A. A. U. W., 1917. Open to women who are nationals of the Latin-American republics, who have had equivalent of a college education in the universities or the best normal schools of their countries, are twenty-one years of age, or more, and have sufficient knowledge of English to profit by lectures, use textbooks and take part in class discussions and examinations. Available for study in some educational institution of the United States. The purpose of the study shall be preparation for some form of public service to their countries in one or more of the following fields: education, including scientific investigation, teaching, library work, etc.; social service; public health and sanitation. Stipend, $1500 a year.

Maltby (Margaret E.) Fellowship. Founded by A. A. U. W., 1926. Open to women who have a degree in arts, science or literature. Stipend, $1500 a year.

Nourse (Mary Pemberton) Memorial Fellowship. Founded in 1925 by Vassar College classmates and friends of Mary Pemberton Nourse. Administered by the A. A. U. W. Open to women who have the bachelor's degree or its equivalent, who also have completed a minimum of either two years of graduate study tending toward public health work (for instance in such subjects as biology, chemistry, the medical sciences, economics, sociology), or two years of practical work in the field of public health. The following three types of work indicate the directions in which it may be used: 1. Extensive study of public health problems and practice abroad or in the United States. 2. Intensive study of some special problems of public health. 3. Study of the science of public health in some approved institution. Offered biennially. Stipend, $1500 a year.

Palmer (Alice Freeman) Memorial Fellowship. Founded by A. A. U. W., 1908. Open to women who have the degree of Ph. D. or D. Sc. and can present evidence of distinctive subsequent accomplishment in research. Stipend, $1500 a year.

Piatt (Julia C. G.) Memorial Fellowship. Founded by the A. A. U. W., 1918, as trustee of the memorial fund given by the Julia C. G. Piatt Association. Open to any woman having a degree in arts, science or literature, who intends to make teaching her profession. In general, preference is given to those applicants who have had successful experience in teaching and in addition have completed at least two years of graduate study. Awarded triennially. Stipend, $1000 a year.

Sidgwick (Rose) Memorial Fellowship. Founded by Americans and the A. A. U. W., in memory of Rose Sidgwick, a member of the British Educational Mission which visited the United States in 1918, and in recognition of her services to the cause of Anglo-American friendship. Open to British women of graduate standing. Available for graduate study in American colleges or universities. Awarded biennially by a committee of the British Federation of University Women. Stipend, $2000 a year. Further information may be obtained from Miss Theodora Bosanquet, Crosby Hall, London, England.

AMERICAN BUREAU OF WELDING, 29 West 39th St., New York, N. Y.

Structural Steel Investigations. Established 1926 to carry out scientific investigations on applications of welding and fabrication of steel structures. Original amount, $25,000. Present amount, $7000. At the present time there is a fellowship at Lehigh University to conduct tests on welded connections in structural work.

AMERICAN FIELD SERVICE FELLOWSHIPS FOR FRENCH UNIVERSITIES, INC., Institute of International Education, 2 West 45th St., New York, N. Y.

American Field Service Fellowships. Number varies; six for 1932-33; five for 1933-34. Founded 1921. Open to men who are citizens of the United States or one of its possessions, American born or of American parentage, who at the time of making the application are graduates of a college of recognized standing or a professional school requiring three years study for a degree; or if not qualified in either of these ways, must be twenty-four years of age and have spent five years in work requiring high technical skill; must be of good moral character and intellectual ability, and of suitable personal qualities, have a practical ability to use French books, both in general subjects and in special field of study, and be able to speak French and understand lectures delivered in French. In the absence of an absolute rule as to age, preference will in all cases be given to candidates between the ages of twenty and thirty years. Available in French universities for general scientific study. Stipend, $1400 a year. Fellowships are tenable for one year. Applications should be filed on or before January 1st with the Executive Secretary. Special application form furnished.

AMERICAN HOME ECONOMICS ASSOCIATION, 620 Mills Bldg., Washington, D. C.

Richards (Ellen H.) Fellowship. Founded 1917. Open to a woman who is prepared to pursue graduate study involving research and who has shown superior ability as an undergraduate in the field of home economics. Available for study in any American University. Stipend, $500 for 1934-35. Applications should be filed on special form by April 1st with Miss Beulah I. Coon, Chairman of Committee on Fellowship Awards, 1800 H St., N. W., Washington, D. C.

Textiles and Clothing Fellowship. Founded 1930 by Omicron Nu for research in textiles and clothing. Open to a woman capable of doing research in textiles and clothing and who has at least one degree from an institution of recognized standing. Available for study in any American university. Stipend, $200 for 1934-35. Applications should be filed by April 1st, 1934, for 1934-35 award, and sent to Miss Beulah I. Coon, Chairman of Committee on Fellowship Awards, 1800 H St., N. W., Washington, D. C.

AMERICAN INSTITUTE OF ARCHITECTS, New York Chapter, Room 732, 522 Fifth Ave., New York, N. Y.

LeBrun Scholarship. Established 1910 by Pierre L. LeBrun, for a European trip of not less than six months for the study of architecture other than by entering schools or ateliers. Open to architects or architectural draftsmen, citizens and residents of the United States, not under 23 nor over 30 years of age, who have been engaged in active practice or employed as architectural draftsmen for at least three years and have not been beneficiaries of any other travelling scholarship. The scholarship is not annual by deed of gift, but was to be $1000 every two years. This was to be given every year if income permitted, however, and has actually been awarded every year since 1921, and the amount increased to $1400. No scholarship will be awarded in 1934. Special application form is furnished.

AMERICAN INSTITUTE OF BAKING, 1135 Fullerton Ave., Chicago, Ill.

While there are no outstanding fellowships or scholarships open at present, there is a possibility that such fellowships may be offered. Anyone interested may obtain information by addressing C. B. Morison at the above address.

AMERICAN PHYSIOLOGICAL SOCIETY.

Porter Fellowship for Physiological Research. Founded by Professor W. T. Porter, Harvard Medical School. Open to both men and women who have shown ability to do research and the prospect of accomplishing something worth while in physiology and closely related fields. Available in any American university under the approval of the Council of the Society. Stipend, $500 a year. Applications should be filed by February 15th with F. C. Mann, Mayo Foundation, Rochester, Minn.

AMERICAN-SCANDINAVIAN FOUNDATION, 116 East 64th St., New York, N. Y.

American-Scandinavian Foundation Exchange Fellowships. Founded 1911. Open to men and women who were born in the United States or its possessions, and who are capable of independent study and research in humanistic and scientific subjects. Available for study in Norway, Denmark or Sweden. Stipend, $1000 a year. Applications should be filed before March 15th at the above address. Special application form furnished.

AMERICAN SCHOOLS OF ORIENTAL RESEARCH, Box 25, Bennett Hall, University of Pennsylvania, Philadelphia, Pa.

Baghdad School Fellowship. For study and research under the supervision of the American School of Oriental Research in Baghdad. Awarded from time to time. Open to any student of one of the Member Institutions of the American Schools of Oriental Research who is prepared to do advanced research in the fields covered by the Baghdad School. The awarding of this Fellowship is in the hands of the Committee of the Baghdad School. Stipend, $1700.

Nies (James B.) Scholarship. For study under the direction of the American School of Oriental Research in Jerusalem. Awarded occasionally. Open to students of the Member Institutions of the American Schools of Oriental Research. Awarding of this Scholarship is in the hands of the Committee of the Jerusalem School (Chairman, President Julian Morgenstern). Stipend, $500.

Thayer Fellowship. For study and research under the supervision of the American School of Oriental Research in Jerusalem. Awarded annually. Open to any student of one of the Member Institutions of the American Schools of Oriental Research who is prepared to do advanced research in the fields covered by the Jerusalem School. Awarding of the Fellowship is in the hands of the Committee of the Jerusalem School (Chairman, President Julian Morgenstern) and carries a stipend of $1500.

AMHERST COLLEGE, Amherst, Mass.

Applications should be filed with the Office of the President.

Kellogg (Rufus B.) University Fellowship. Founded by Rufus B. Kellogg. Awarded every seven years for a period of seven years. The last four years of the term shall be spent as a lecturer at Amherst College, but the incumbent shall not give more than thirty lectures per annum and shall not be required to reside at Amherst more than one college term of any year. The lectures shall be upon a subject selected by the Fellow himself and approved by the Trustees and shall be given to the Senior class, but members of all classes shall have the privilege of attending. Fellow shall have no occupation or employment during the tenure of the fellowship except such as pertains to the duties of the office. The first three years are to be spent at a German university or, with the approval of the Faculty of Amherst, at any other place or places. Open to alumni of Amherst College, either members of graduating class or of class graduated within six years of time of receiving award. Stipend, $1500 a year.

Moore (Forris Jewett) Fellowship in Chemistry. Founded by Mrs. Emma B. Moore. Open to men who are members of graduating class of Amherst College. Available in any American university or abroad for study and research in chemistry, preferably organic chemistry. Stipend, $500 a year.

Simpson (John Woodruff) Fellowships. One or two annually. Founded by Mrs. John Woodruff Simpson and Miss Jean Simpson. Open to graduates of Amherst College, preference being given to members of graduating class. Available at Oxford or Cambridge or at the Sorbonne for general scientific study, or in this country for law, medicine or theology. Stipend, $1500 to $1800 a year.

ARIZONA, UNIVERSITY OF, Tucson, Ariz.

Applications should be filed not later than April 1st with the Head of the Department in which the fellowship is held, unless otherwise noted.

Arizona Bureau of Mines Fellowships. Two. Through the Arizona Bureau of Mines the University offers two fellowships to men holding a bachelor's degree who have specialized in metallurgy or chemistry as undergraduates. Each fellowship pays $600 per year; the fellows are expected to put half their time during the academic year upon research work for the United States Bureau of Mines Experiment Station located on the Campus of the University. Time not utilized in this way must be spent in study in candidacy for an advanced degree. Applications should be filed prior to May 1st with the Dean, College of Mines and Engineering.

Chemistry Fellowship. Open to graduate student doing advanced work in chemistry. Stipend, $300 a year.

Home Economics Fellowship. Open to women graduate students doing advanced work in home economics. Stipend, $350 a year.

Nutrition Fellowship. Open to graduate student doing advanced work in nutrition. Stipend, $480 a year. Applications should be sent to the Head of the Department of Agricultural Chemistry.

Teaching Fellowships in Geology. Two. Founded by the University, 1925. Open to men who have majored in geology and made exceptionally high grades as undergraduates. Teaching fellows are required to assist in laboratory work, in the preparation of material, etc., and can ordinarily earn the master's degree in two academic years. Stipend, $400 per academic year; about twelve hours per week required in service.

Teaching Fellowships in Metallurgy. Two. Open to men who have majored in metallurgy and made good records as undergraduates. Teaching fellows are required to assist in laboratory instruction, and in preparation of materials and equipment. Fellows can ordinarily earn the master's degree in two academic years. Stipend, $200 a year. Ten hours per week required as laboratory assistant.

Zoology Fellowship. Open to graduate student doing advanced work in zoology. Stipend, $400 a year.

ARKANSAS, UNIVERSITY OF, Fayetteville, Ark.

Jones (Coulter W.) Scholarship. Founded 1933 for graduate study in chemistry. Open to men and women, who are graduate students, for work in this University. Stipend, $250 to $350 a year. Application should be filed with the Head of the Department of Chemistry on or before April 1st.

BARTOL RESEARCH FOUNDATION OF THE FRANKLIN INSTITUTE,
Whittier Place, Swarthmore, Pa.

Bartol Research Foundation Fellowships. Founded 1923 by Henry W. Bartol. Number varies, but about six are awarded annually. Open to men with the equivalent of the Ph. D. of National Research Fellowship grade, with preference given to those under 30 years of age, for research in fundamental problems in physics, and particularly in electrical and atomic structure. Available only in the Foundation. Stipend, $1600 to $2500. Application should be filed, on special blank furnished for the purpose, by April 1st.

BATTELLE MEMORIAL INSTITUTE, 505 King Ave., Columbus, Ohio.

Research Fellowships. Each fellowship carries an honorarium of sixty dollars per month for ten months, from September to June, inclusive. All course work selected by the fellow is taken at Ohio State University, while the research work is carried on at Battelle Memorial Institute. Candidates for research work must have specialized in metallurgy, fuels, ceramics or allied fields. Ordinarily, each fellow is a candidate, either for the degree of Master of Science or Doctor of Philosophy and applies his entire time to graduate study and research. Candidates may secure application blanks by addressing the Dean of the Graduate School of Ohio State University or the Director of the Institute. All applications should be received not later than March 1st of each academic year.

Sponsored Research Projects. The Institute, being a non-profit organization, offers, to industries or individuals, at cost, the facilities of its laboratories and staff for the solution of research problems in the lines for which it is equipped. Activities include problems relating to alloy steel, aluminum, bearing metals, briquetting, cadmium, cast iron, cements, coal, coal cleaning, coke, combustion, copper, copper alloys, corrosion, creep of metals, electric furnaces, electroplating, enamels, fluxes, galvanizing, hydrometallurgy, ingot molds, insulating materials, malleable iron, metallography, molding sands, ore concentration, radiation from flames, refractories, sheet steel, sintering, special alloys, steel castings, structural steel, thermal conductivity, temperature control, vacuum melting, zinc and others.

BISHOP (BERNICE P.) MUSEUM, Honolulu, Hawaii.

Bishop Museum Fellowships. Two. Founded 1921 by the Museum and Yale University, for research in ethnology and natural history of Oceania. Open to men and women with advanced graduate study or the Ph. D.

degree. Problems are restricted to the Pacific region and fellowship is generally assigned for field work in the Pacific. Stipend, $2000 a year. Applications should be filed by March 1st on special form furnished by Yale University or the Bishop Museum.

BOSTON UNIVERSITY, Boston, Mass.

Buck (Professor Augustus Howe) Educational Fund. Number varies; five in 1932-33, eight in 1933-34. Founded 1916. Only students who have been undergraduate beneficiaries of the Fund receive appointment as Fellows. Preference is given to candidates preparing for work in pure science, education, medicine, the ministry or similar fields. Appointments may be made in the Freshman year and not later than the middle of the Junior year; may be renewed yearly throughout the college course, a period of graduate study and one or two years of professional study or travel. Applications should be filed with the Registrar. Special application form furnished.

Draper (Ada) Fund. Founded by the will of Ada Augusta Draper, formerly of Boston, to establish scholarships, and to enable the most meritorious and needy female students to be sent to Europe after graduation to complete their studies.

Sleeper (Jacob) Fellowship. Founded by Trustees of this University in recognition of the last gift of the Hon. Jacob Sleeper, 1889. Open to men. Available in this University for preparation for teaching in colleges and theological schools. Stipend, $750 a year; holders carrying on their work in residence are expected, if called upon, to render assistance in teaching or otherwise. Appointments are made twice in three years. Applications should be filed before February 1st with the Dean. Special application form furnished.

BOSTON SOCIETY OF ARCHITECTS, Boston, Mass. Address, Niels H. Larsen, 814 Statler Bldg.

Kelley (James Templeton) Fellowship. Established 1929 by Mrs. James Templeton Kelley in memory of her husband. Open to both men and women, in the area of Maine, New Hampshire, Vermont, and Massachusetts, preferably over thirty years of age, who are architects or draftsmen in practice; not open to students in schools of architecture. Primarily intended for study abroad, the program of travel and study to be outlined by the candidate and approved by the administration of the Fellowship. Stipend, not over $2500 a year. No fixed date for applications to be received, but usually about January 18th.

Rotch Traveling Scholarships. Two. Founded by Benjamin S. Rotch, 1883. Open to men and women who have had two years' office experience or three years in an architectural school and one year in an office, are under thirty years of age and citizens of the United States. Available for the study of architecture abroad. Stipend, $1500 a year for two years. Applications should be filed any time before the examinations, which usually occur about April 10th, with C. H. Blackall, Secretary, 31 West St., Boston, Mass.

BOWDOIN COLLEGE, Brunswick, Maine.

Everett (Charles Carroll) Scholarship. Founded by Miss Mildred Everett, 1903. Open to men of very high rank, at least in chosen field, in senior class at Bowdoin. While this scholarship is not confined to science, often, if not generally, it is awarded for graduate work in science. Stipend, $500 to $700 a year. Applications should be filed by February 1st with the President of the College.

Garcelon and Merritt Fund. About $10,000 from the income of this fund, established in memory of Seward Garcelon, of the Medical Class of 1830, and Samuel Merritt, of the Medical Class of 1843, is appropriated annually for medical scholarships. Applications must be made upon blank forms furnished by the President of the College and must be received before December 1st.

BROWN UNIVERSITY, Providence, R. I.

Applications should be filed by March 1st with Registrar of Graduate School. Special application form furnished.

Abbott's (Miss) School Alumnae Fellowship. Founded 1930 for general scientific study. Open to women, not more than 30 years old at appointment, with at least one year of graduate work. Awarded by preference to graduates of Pembroke College, or women who have spent one or more years in the graduate school. Available for study in any American university or abroad.

Anthony (Edwin P.) Fellowship. Founded 1931 by Emily J. Anthony for the study of chemistry. Open to men and women who are graduate students. Stipend, $300 to $600 a year. Available only in this University.

Arnold (Emma Josephine (Ayer)) Archaeological Fellowship. Founded by Dr. Oliver Henry Arnold, 1913. Awarded by preference to graduates of Pembroke College within ten years after receiving the bachelor's degree. Available in this University for the study of archaeology primarily, but awarded for mathematics if there is no applicant in that subject. Stipend, $500 a year.

Arnold (Oliver Cromwell Gorton) Biological Fellowship. Founded by Dr. Oliver Henry Arnold, 1913. Open to men and women, preferably with one year of graduate work. Available for study in the Department of Biology of this University. Stipend, $500 a year.

Emery (Anne Crosby) Alumnae Fellowship. Founded by Alumnae Association of Brown, 1914. Open to members of graduating class of Pembroke College. Available for graduate study in any American University or abroad. Stipend, $500 a year. Awarded as an academic honor and cannot be applied for.

Geological Fellowship. Founded by Mr. and Mrs. D. Albert Peirce, 1920. Open to men and women with a bachelor's degree. Available in this University for the study of geology. Stipend, variable.

Graduate Assistantships and Instructorships. Approximately thirty. Open to those who have had advanced work. Half-time must be given to undergraduate class room or laboratory instruction or to assisting in research, other half to graduate work. Stipend, $500 to $750 plus tuition (and occasionally more).

Grand Army of the Republic Fellowship. Founded by Grand Army of the Republic, Department of Rhode Island, 1891. Open to men with a bachelor's degree from Brown. Available in this University for general scientific study. Stipend, $500 a year.

Marston (Edgar Lewis) Fellowship. Founded by Edgar L. Marston, 1920. Open to men and women who have received the bachelor's degree from the University of Texas. Available in this University for general scientific study. Stipend, $500 a year.

Marston (E. L.) Scholarship. Founded by E. L. Marston, 1904. Open to men who have received the bachelor's degree from Baylor University, Waco, Texas. Available in this University for general scientific study. Stipend, $500 a year.

Marston (Edgar Lewis) Scholarship. Founded 1902, by Edgar L. Marston, for general scientific study. Open to men and women with a bachelor's degree, who are graduates of Simmons University (Texas). Available only at this University. Stipend, approximately $350 a year.

Marston (S. W.) Scholarship. Founded by Edgar L. Marston, 1900. Open to men and women with a bachelor's degree from William Jewell College (Missouri). Available in this University for general scientific study. Stipend, $250 a year.

Metcalf (Jesse) Fellowships. Three or four. Founded by Jesse Metcalf, 1923. Open to men who have had one year of graduate work. Available in this University for the study of chemistry. Stipend, $700 to $1000 a year.

Morgan (Edwards) Fellowship. Founded by Philadelphia alumni of Brown, 1914. Open to men who, within ten years, have received the bachelor's degree from Brown, and, in general, have done two years of graduate work. Available for study in any American university or abroad. Stipend, $1000 a year. Awarded bi-annually.

University Graduate Scholarships. Approximately five. Founded 1930 for general scientific study. Open to men and women with a bachelor's degree. Available in this University only. Stipend, tuition.

University Graduate Scholarships in Chemistry. Four to six. Founded by the University, 1924. Open to men with a bachelor's degree. Available in this University for the study of chemistry. Stipend, tuition ($300).

University Junior Fellowships. Six. Founded by the University, 1927. Open to men and women with one year of graduate work. Available in this University. Stipend, $500.

University Research Fellowships in Chemistry. Six. Founded by the University, 1924. Open to men with one year of graduate work. Available in this University for study in chemistry. Stipend, $500 to $750.

BRYN MAWR COLLEGE, Bryn Mawr, Pa.

Bryn Mawr European Fellowship. Founded by the College, 1889. Open to members of the graduating class on the ground of excellency in scholarship. The Fellowship is to be applied toward the expenses of one year's study and residence at some foreign university. Stipend, $500 a year. No application is made for this fellowship as the holder is selected from the ten highest in the Senior class. The holder also receives the Elizabeth S. Shippen Foreign Scholarship of the value of $200.

Garrett (Mary Elizabeth) European Fellowship. Founded 1894 and combined in 1927 with the President M. Carey Thomas European Fellowship, which was founded in 1896. Offered as a single Fellowship. Open to students still in residence who are candidates for the degree of Doctor of Philosophy at Bryn Mawr College. Stipend, $1000 a year. Awarded on the ground of excellence in scholarship, therefore no application is made. Nominations are made by the departments and the holder is elected by the Faculty.

Huff (Helen Schaeffer) Memorial Research Fellowship. Founded 1913. Open to students who have done advanced graduate work at some college or university of recognized standing and have shown capacity for research. Available for study of physics and chemistry. Where equally good candidates are considered, preference will be given to a student working on problems which may be considered to lie along the borderline between chemistry and physics. Fellowships are generally held at Bryn Mawr, but may be held during one year's work at some other American college or university, if it is imperative in order to complete an important piece of investigation. Stipend, $1200 a year. Applications should be filed by March 1st with the Dean of the Graduate School.

Resident Fellowships. Twenty-one in biology, geology, chemistry and physics. Open to women holding the A. B. degree from a college or university of acknowledged standing who have completed (in addition) at least one full year of graduate work. Reserved for American women, including Canadian. Stipend, $860 a year. Applications should be filed by March 1st with the Dean of the Graduate School. Special application form furnished.

Resident Scholarships. One offered for each department of the College, therefore, four for science—biology, chemistry, geology and physics. Open to women who have the A. B. degree from a college or university of acknowledged standing. Stipend, $400 a year. Applications should be filed by March 1st with the Dean of the Graduate School. Special application form furnished.

Scholarships for Foreign Women. Number varies in different years but not more than five. Open to women who have had training equivalent to that denoted by the A. B. degree of an American college or university of acknowledged standing and who can speak and understand English. Available for study in the Graduate School of Bryn Mawr College. Stipend, $1000 a year. Applications should be filed by April 1st with the Dean of the Graduate School. Special application form furnished.

Workman (Fanny Bullock) Fellowship. Founded 1927. Open to candidates for the Ph. D. degree at Bryn Mawr who could not have the advantages of such a year without assistance. Available for study or research abroad. Stipend, $1500 a year. Application is not made for this Fellowship. Award is made by Faculty on basis of nominations from various departments.

BUCKNELL UNIVERSITY, Lewisburg, Pa.

Burpee Fellowship in Genetics. Founded 1933, by David Burpee of the Burpee Seed Company, for research in genetics. Annually available,

$500 and free tuition. Applications should be filed before May 1st with Professor W. H. Eyster.

Graduate Fellowships. Five. Open to men and women with the bachelor's degree for any type of graduate work. Stipend, $200 a year and tuition. Holders may be required to render service.

Graduate Fellowships. Ten. Open to men and women with bachelor's degree from Bucknell University. Stipend, free tuition. Application must be filed with the President before May 1st.

BUFFALO, UNIVERSITY OF, Buffalo, N. Y.

Fellowships (four in chemistry, two in physics, one in biology, and two in mathematics) are offered to college graduates for study in these subjects at the University of Buffalo. Stipend, $500 a year for each fellowship; the number of hours per week required in service is not definitely stated in advance but depends on the individual's plans and qualifications. Applications should be filed by March 1st with the Chairmen of these Departments. This information applies to the academic year 1933-1934.

C. R. B. EDUCATIONAL FOUNDATION, INC., 42 Broadway, New York, N. Y.

C. R. B. Fellowships. Three or four annually. Founded 1920, for general scientific study in Belgium. Open to men and women who are members of faculties of universities, colleges, or research institutes, of American citizenship, good health and knowledge of French or Flemish. Stipend, $120 monthly plus travel and other allowances. Applications should be filed on special form, by December 15th for the following year.

CALIFORNIA, UNIVERSITY OF, Berkeley, California.

Except when otherwise stated, applications should be filed with the Dean of the Graduate Division by February 20th. Awards will be made not later than April 1st. Standard application forms for all fellowships and graduate scholarships will be furnished on request.

Agriculture Fellowship. Established 1932, by gift of an anonymous donor. Open to graduate students of either sex. Available for study of one of the agricultural sciences at the University of California. Award suspended for the present.

Alameda County Nurses Association Fellowship. Established 1928, by the Alameda County Nurses Association. Open to members of the Association at any institution of collegiate grade. Available for resident study or for a traveling fellowship in any study. Award suspended for the present.

Architecture Traveling Fellowship. Established 1925 by subscription. Open to graduate students, of either sex, in architecture. Awarded irregularly. Last award, $800.

Baker Fellowship in Forestry. Established 1929 by appropriation of a portion of the annual income from the Forestry Endowment Fund. Open to graduate students, citizens of the United States, who wish to pursue research and advanced study in forestry at the University of California, and who have at least twenty units in forestry in a school of good standing. Stipend, $750 a year.

Base Hospital No. 30 Scholarship in Medicine. Established 1920 from unexpended balance of funds collected for the University of California Medical School Base Hospital Unit No. 30 in the World War. Open to medical students of either sex at the University of California. Stipend, 1933-34, $360.

Bidwell Fellowship in Forestry. Established 1929 by appropriation of a portion of the annual income from the Forestry Endowment Fund. Open to graduate students, citizens of the United States, who wish to pursue research and advanced study in forestry at the University of California, and who have at least twenty units in forestry in a school of good standing. Stipend, $750 a year.

Bush (Alice) Scholarship in Homeopathy. Open to medical students, preferably women, at the University of California who wish to pursue study in homeopathy. Stipend 1932-33, $325.

Cates (Dudley) Fund. A research fellowship in surgical research related to the problems of the central nervous system is offered yearly to a graduate student under the Dudley Cates Fund. Applications should be submitted to Dr. H. C. Naffziger, Professor of Surgery.

Claypole (Edith) Memorial Research Fellowship. Established 1915, by Agnes Claypole Moody and Norman Bridge. Open to students, preferably women, pursuing graduate study in pathology or bacteriology, for the encouragement of investigation of problems in pathology, particularly researches in diagnosis and specific therapy of infectious diseases. Stipend 1933-34, $1100.

Denman (James) Memorial Scholarship. Established 1922, by bequest of James Denman. Available to deserving young women, graduate or undergraduate, at the University who are preparing to enter upon some municipal or quasi-public employment having in view the systematic regulation, care and fostering of the recreation of young people in large cities. Stipend 1933-34, $200.

Dentistry Traveling Fellowship. Established 1926, by alumni and friends of the College of Dentistry. Open to dental graduates or persons whose field of study has been closely allied to dental science. Restricted to study in dental art or science or an allied field. Award suspended for the present.

Douglass (George A.) Scholarships. Established 1925, by bequest of George A. Douglass. Open to men with high scholarship records who are residents of the State of California, of commendable character and in need of financial assistance, who desire to study at the University. Award suspended for the present.

Fleischner (E. Charles) Memorial Fellowship. Supported by the Trustees of the E. Charles Fleischner Endowment Fund. Open to graduate students in the Medical School who desire to pursue investigations on problems in pathology and bacteriology. Stipend 1933-34, $900.

Gayley (Charles Mills) Fellowship. Established 1925, by friends of the late Charles Mills Gayley. Awarded without applications to graduate students in any department upon basis of possession of qualities of leadership, character and future promise. The appointee may pursue his studies at the University or elsewhere. Stipend 1933-34, $300.

Goewey (James M.) Fellowship. Established 1904, by the family of the late James M. Goewey. Open to graduate students in any one of the so-called scientific branches of learning. Stipend 1933-34, $750.

Heller (Emanuel S.) Memorial Scholarship. Established 1926, by Mr. and Mrs. Sidney M. Ehrman. Open to students in the graduate division, or to Juniors or Seniors. Stipend 1933-34, $375.

Heller (Hattie) Graduate Scholarship. Established 1921, by an anonymous donor. Awarded to graduate students, in any department of the University, on the basis of scholarship and need. Stipend 1933-34, $500.

Heller (Samuel W.) Memorial Fellowship in Landscape Design. Established 1929, by Walter S. Heller. Open to graduate students in landscape design. Stipend 1933-34, $650.

Heller (Sigmund Martin) Traveling Fellowship. Established 1924, by E. S. Heller. Open to graduates of the University for study at any American university or abroad. Stipend 1933-34, $1200.

Honorary Traveling Fellowships. Open to distinguished graduates of any department of the University. The fellowships entitle the holders to official credentials from this University to any American university or abroad. No stipend.

Howard (Bruce) Memorial Scholarships. Established 1919 by Helen L. Howard. Available for students in chemistry. Stipend 1933-34, $200-$400.

Italian-American Fellowships. Established 1929. (A). Open to graduate students in the University of California who desire to study at one or more of the universities or other centers of scholarship in Italy. Applicants must have a knowledge of Italian. (B). Open to graduates of Italian universities who have some knowledge of English and who desire to carry on advanced study in the University of California. These fellowships have been suspended for the present.

Johnson (Amy Bowles) Memorial Fellowships. Established 1927 by Mrs. Philip E. Bowles. Open to graduates of the University. Awarded on the basis of scholarship, character and personality. Stipend, not less than $1200 a year.

Jordan (Alfred B.) Fellowship. Established 1931, by the bequest of Alfred B. Jordan. Open to graduate students who have come to the United States from Germany for advanced study, which must be conducted at the University of California. Stipend 1933-34, $900.

Kellogg (Martin) Fellowship in Astronomy. Established 1911 by Dr. W. W. Campbell. Available for fellowship at the Lick Observatory. Stipend 1933-34, $950.

Kraft (Herbert) Scholarships. Established 1917 by George H. Kraft. Available to graduates of Tehama County, California, high schools for study in agriculture. Stipend 1933-34, $250-$300.

LeConte Memorial Fellowship. Established 1898 by the LeConte Memorial Fellowship Committee. Open to graduates of the University. Awarded on the basis of scholarship and ability for original research. Available for study at any American university or abroad. Stipend 1933-34, $600.

Lick Observatory Fellowships. Two. Established 1898 by the University. Available for study at Lick Observatory. Awarded on basis of scholarship and capacity for original research. Applications should be filed by February 20th with the Director of the Lick Observatory, Mount Hamilton, California.

Loewy (Walter) Scholarships. Established 1933 by the bequest of Walter Loewy. Available to needy students from Germany for study at the University, or to students from the University of California for study at Heidelberg.

McDonald (James Monroe) Scholarships. Seven. Established 1921-27 by Mary J. L. McDonald. Available for men. Primarily for undergraduates but may be awarded for a year of graduate study at the discretion of the department concerned. One each in physics, mining engineering and chemistry; two each in agriculture and in civil engineering. Stipend 1933-34, $400-$575.

Mack (J. J. and Nettie) Memorial Foundation. A fellowship is provided by this Foundation, which combines clinical and research opportunities in thoracic surgery and correlated research problems. It is open to graduates in an advanced stage of training. Applications should be filed with Dr. H. C. Naffziger, Professor of Surgery.

Mackay (John W., Jr.) Fellowship in Electrical Engineering. Established in 1906 by Clarence H. and Marie E. Mackay. Available for research in electrical engineering at the University. Stipend 1933-34, $600.

Morrison (Alexander F.) Fellowship in the Lick Observatory. Established 1928 by Mrs. A. F. Morrison. Available to graduate students for study at the Lick Observatory. Stipend 1933-34, $1200.

Pacific Coast Gas Association Research Fellowship in Gas Engineering. Supported by the Pacific Coast Gas Association. Open to senior and graduate students, of the current academic year, in the engineering departments of colleges and universities in British Columbia, Washington, Oregon, California, Idaho, Nevada and Arizona. Stipend 1933-34, $750.

Rosenberg (James) Memorial Scholarships in Agriculture. Established 1919 by gift of Mrs. Linda and Joseph Rosenberg. Open to graduate students in the College of Agriculture qualified to conduct research contributing to the welfare of California agriculture. Stipend, one at $125 and one at $600.

Sanborn (Sheffield) Scholarship in Medicine. Established 1910 by Mrs. Frances B. Sanborn. Three scholarships, one of which is for a student of medicine in the University who has not received a professional degree. Stipend 1933-34, $240.

Shell Research Fellowship. Supported by the Shell Development Company. Available for graduate study in chemistry at the University. Awarded on basis of merit in chemical research. Stipend 1933-34, $900.

Stebbins (Horatio) Scholarship. Established 1913 by a friend. Primarily for undergraduates but may be awarded to a graduate student. Open to women only.

Taussig (Bertha Henicke) Memorial Scholarship. Established 1914 by bequest of Hugo A. Taussig. Available to women students for resident study or as a traveling fellowship. Preference is given to students in the following fields of study in the order named: first, art; second, architecture; third, literature. Stipend 1932-33, $500.

Taussig Traveling Fellowship. Established 1923 by the bequest of Rudolph J. Taussig. Open to graduates of the University. Stipend 1933-34, $1250.

Teaching Fellowships and Assistantships. Supported by the University. These require that about one-half time be devoted to teaching duties. Stipend, $600 in most cases. Applications should be addressed to the President of the University, through the Chairman of the department concerned.

Thompson (Willard Dawson) Memorial Scholarships. Established 1908 by the bequest of Jennie D. Thompson. Open to residents of Utah for study at the University. Stipend 1933-34, $600-$750.

University Fellowships. Supported by the University. Open to graduate students who have given evidence of ability to carry on research. Stipend 1933-34, $600.

Watson (Mary J., M.D.) Scholarship. Established 1918 by Dr. James W. Ward. Open to students from Sacramento, California, studying homeopathy at the University of California Medical School. Stipend 1932-33, $140.

Weiss (Ephraim and Amalia) Scholarships. Established 1922 by Ephraim and Amalia Weiss. Open to senior or graduate students in chemistry, physics or philosophy. Awards are suspended for the present.

Whiting Fellowships in Physics. Established 1897 by the bequest of Professor Harold Whiting. Awarded on the basis of scholarship and proven ability for research. Stipend 1933-34, $600.

Wilson (Allen D.) Memorial Scholarships. Established 1931 by the bequest of Amelia E. S. Wilson. Open to students of good moral character who profess a belief in God, and who, without such aid, would not be able to obtain the advantage of advanced education. Available for study in engineering, medicine, law and education. Awards suspended for the present.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, Calif.

Applications should be filed by March 1st with Chairman, Committee on Graduate Studies. Special application forms furnished.

Exchange Fellowship with Germany. Open to men. Qualifications, B. S. degree or equivalent. Stipend, room, board and tuition. Arranged through Institute of International Education.

High Potential X-Ray Research Fellowships and Assistantships. Four. Open to men. Requirements same as for Teaching Fellowships and Assistantships, *which see.* Stipend, $300 to $900 a year.

Laws (Henry) Fellowships in Physics, Chemistry and Mathematics. Seven. Open to men with experience equivalent to that of master's degree. Stipend, $300 to $900 a year. Not over twelve hours per week required in service, including preparation.

Teaching Fellowships and Assistantships. These fellowships in general require experience equivalent to master's degree; the assistantships require completion of undergraduate work containing thorough courses in chemistry, physics and mathematics. Stipend, $300 to $900 a year; not over twelve hours per week required in service, including preparation. The following subjects are represented: chemistry, fifteen; mathematics, eleven; physics, fifteen; civil engineering, mechanical engineering and aeronautics, twenty-seven; electrical engineering, eight; teaching fellowships in biology, eight.

CARNEGIE INSTITUTE OF TECHNOLOGY, Pittsburgh, Pa.

Fellowships in the Coal Research Laboratory. A limited and indefinite number of fellowships may be awarded in the Coal Research Laboratory. These fellowships are open to men who have already completed one year of graduate study in chemistry. The stipend may range from $600 to $1000. The holder will be expected to continue graduate study and do research in the Coal Research Laboratory, fulfilling the conditions leading to a degree of Doctor of Science in the Carnegie Institute of Technology. In the school year 1933-1934 three such fellowships have been awarded. Application for fellowships should be sent to the Coal Research Laboratory.

Metallurgical Advisory Board Fellowships. These fellowships in metallurgy were established in cooperation with the Metallurgical Advisory Board. Fellows are required to register for an advanced degree. The stipend is $750 per year and free tuition.

Mining Advisory Board Fellowships. These fellowships were established in cooperation with the Mining Advisory Board. Research problems assigned pertain to the study of coal. Fellows are required to register for the degree of Master of Science. The stipend is $500 per year and free tuition.

Teaching Fellowships. Teaching fellowships are awarded in Chemistry, Physics and Engineering. The teaching fellows are required to register for an advanced degree. The stipends are $400 or $600 and free tuition.

CARROLL COLLEGE, Waukesha, Wis.

Graduate Scholarship. *See* Wisconsin, University of. Graduate Scholarships.

CASE SCHOOL OF APPLIED SCIENCE, Cleveland, Ohio.

Assistantships. At the present time, a group of half-time assistants are appointed in the various laboratory departments; in general, these are confined to graduates of the School. The assistants receive a cash stipend of $500 a year together with a remission of tuition and are able to complete the requirements for the master's degree in two years.

Drury Fellowships. Founded by F. E. Drury, 1917. Open to men who are graduates from a recognized college. Available in this School for study in engineering, chemistry or physics. Suspended for the present.

CATHOLIC UNIVERSITY OF AMERICA, Washington, D. C.

Knights of Columbus Scholarships. Established 1914 by the Knights of Columbus with an endowment of $500,000. This provides board, room and tuition for twenty-five laymen, selected by competitive examination for graduate work in arts and sciences or in law, in the Graduate School of Arts and Sciences or in the graduate divisions of the Schools of Law or Engineering. For information address Professor Richard J. Purcell, General Secretary.

CELLER (HERBERT L.) FOUNDATION FUND, Dr. Benjamin Eliasoph,
1050 Park Ave., New York, N. Y.

Fellowship. An annual fellowship, of about $1000, depending on the income for the year, is given usually to a graduate in medicine who is in need of financial aid in order to continue his studies or to do research. The grant is usually made in November and applications are called for two months before.

CHAPPEL FOUNDATION FOR ORGANOTHERAPEUTIC RESEARCH, Rockford, Ill.

Established 1931 by Chappel Brothers, Inc., for investigation of medical and physiological qualities of preparations derived from animal sources. Annually available, $25,000. Fellowships are granted for special purposes to scientific men in universities as it may seem advisable to the donors. A chemical-physiological laboratory is maintained at Rockford, Ill. Furthermore, a fellowship is maintained at Northwestern University in combination with Cook County Hospital for a licensed physician part time, assisted by a laboratory technician working full time. The object of the fellowship is clinical observation of material prepared by the laboratory. The fellowships are not necessarily confined to Northwestern University, and can be granted for special purposes to scientific men in other universities as it may seem advisable to the donors.

CHICAGO, THE UNIVERSITY OF, Chicago, Ill.

Applications should be filed on or before March 1st with the Committee on Fellowships and Scholarships, Cobb Hall, Room 203. Annual appointments are made April 1st and appointees given until April 15th to accept or decline. A Fellowship is available for any three of the four quarters, beginning with the summer quarter, following the date of appointment. Full time is to be devoted to graduate study unless special permission has been secured in advance from the Chairman of the Committee on Fellowships and Scholarships. In general, candidates must have spent at least one year in resident study after receiving the bachelor's degree. In making appointments special weight is given to dissertations indicating the candidate's ability to conduct original investigation.

American-German Student Exchange Fellowship. Awarded annually by the Chicago branch of this organization to an advanced student of German nationality. (Not available 1933-34.)

Assistantships. A few departments of the University have part-time teaching or laboratory service to be done by assistants. Appointments are made by the Chairman or Head of department, ordinarily from those persons who have begun residence work in the University of Chicago. Stipend varies in amount according to the type of service rendered and the length of appointment. Assistants pay regular tuition fees and are restricted to less than full work during the term of their appointments.

Barnard (Edith) Memorial Fellowship in Chemistry. Founded 1919, by the family and friends of Miss Barnard. Open to women who are graduate students in chemistry and awarded on recommendation of the Department of Chemistry.

Billings (Dane) Memorial Fellowship in Medicine. Founded by Dr. Frank Billings. Available in Rush Medical College for research in medicine.

Brower (Daniel R.) Fellowship. Available for research in neurology in the Department of Medicine, Rush Medical College.

Brown (Permelia) Scholarships. Provided for under the will of Permelia Brown. Open to unmarried American-born women students, graduate or undergraduate, who are residents of Chicago. Available, but not established for research.

Coman (Seymour) Research Fellowships. Founded 1923, by Seymour Coman. Open to men and women with an M. D. or Ph. D. degree. Available in this University for research in preventive medicine, cause, prevention and cure of diseases. Applications are not received for this fellowship. Candidates are chosen by the Committee.

Corn Industries Research Fellowships. Two. Established by the Corn Industries Research Foundation. The subjects of researches are: "Fatigue in children, with some attention to the nutritional aspects involved therein," under the direction of the Department of Pediatrics; "Effects of the various sugars on normal metabolism, with special respect to hunger, appetite and gastric secretion," under the direction of the Department of Physiology. Stipend, $2500 each.

Coulter (John M.) Research Fellowship in Botany. Endowed by staff members and Doctors of Philosophy of the Department of Botany. Open to persons holding the Ph. D. degree, but ordinarily awarded to candidates for that degree under the Department of Botany.

du Pont Fellowship in Chemistry. Donated certain years to the University of Chicago by E. I. du Pont de Nemours and Company. Open to men and women who are graduate students of the University. Available in this University for the study of chemistry. (Not available 1933-34.)

Fellowship in Pathology. Awarded on recommendation of the Department of Pathology of Rush Medical College.

Friedberg (Stanton Abeles) Fellowship in Laryngology and Otology. Founded 1921, by Mrs. Stanton A. Friedberg. Open to men and women who are graduate students in laryngology and otology. Available in Rush Medical College for research in these subjects. Awarded by the Committee on Fellowships only on recommendation of the Dean of Rush Medical College and the Department of Otolaryngology. Applications should be filed with the Dean of Rush Medical College.

Graduate Honor Scholarships. About fifteen. Awarded to students who have completed, with distinction, the work for the bachelor's degree. Awards are made by the Deans of the Divisions, upon the recommendation of the various departments, with the approval of the Chairman of the Committee on Fellowships and Scholarships.

Graduate Service Scholarships. A limited number of these are available for students of attainment and promise who are studying for higher degrees. These scholarships yield an amount equivalent to the tuition fees in return for service to the departments in which the scholarships are awarded. Application should be made to the Committee on Fellowships and Scholarships before March 1st.

Hardy (Francis A.) Fellowship in Surgery and Assistant House Surgeonship in the Presbyterian Hospital. Founded by Mr. F. A. Hardy. Awarded by the Department of Surgery of Rush Medical College to a graduate in medicine.

Hyde Memorial Fellowship. Founded 1912. Available under the direction of the Chairman of the Department of Dermatology in Rush Medical College for research in skin diseases and cancer.

Ingals (E. Fletcher, Jr.) Fellowship in Laryngology and Otology. Awarded to a physician who is seeking to qualify himself for the practice of laryngology and otology. Opportunity is afforded the holder of this fellowship for advanced work and clinical training.

Lilly Research Fellowships in Chemistry. Founded by Eli Lilly and Company. Available for research in the Department of Chemistry.

Loewenthal (Joseph B.) Fellowship in Chemistry. Founded by Mr. Barthold Loewenthal, of Chicago, as a memorial to his son. Open to graduate students, men and women. Income available for research in the Department of Chemistry and awarded on the nomination of the Department and the approval of the Chairman of the Committee on Fellowships and Scholarships. (Not available 1933-34.)

Logan (Mr. and Mrs. Frank G.) Research Fellowships. Founded by Mr. F. G. Logan. Available for research in the Departments of Medicine, Surgery, Bacteriology or Pathology. Open to men and women graduate students. Awarded on recommendation of heads of respective departments. No applications received.

Lowenstein (Arthur) Research Fellowships. Founded in connection with the Institute of Meat Packing. These fellowships require that the results of research be made available to the entire meat packing industry.

Fellows work under the direction of the Chairman of the Department of Hygiene and Bacteriology. Awarded by a joint administrative committee of the Institute and the University of Chicago.

Luckhardt (Arno B.) Fellowship. For physiological research.

Morse (Herbert A. and Harriet E.) Aid. Available for aid to worthy and needy persons desiring to attend or attending the University of Chicago. Both graduate and undergraduate students are eligible. Available, but not established for research.

Noyes (La Verne) Foundation. Gift of Mr. La Verne Noyes, 1918. Provides part scholarships in any school of the University for deserving students who shall themselves have served in the Army or Navy of the United States in the World War, providing such service was terminated by honorable discharge, or shall be descendants by blood of anyone in service in the Army or Navy of the United States who served in said war, or shall be descendants by blood of anyone who served in the Army or Navy of the United States in said war, provided that such service was terminated by an honorable discharge.

Quaker Oats Co. Research Fellowship. Subject of research: " Effect of radiated yeast in rickets." To be conducted jointly by Home Economics Department and the division of Orthopedic Surgery.

Raymond (Anna Louise) Fellowship in Medicine. Awarded biennially in support of work directed by Dr. Wilber E. Post.

Raymond (James Nelson) Scholarships. Established by Mrs. Anna Louise Raymond, to provide partial tuition fees for two worthy and needy students in the Medical School.

Ryerson (Edward L.) Fellowships in Archaeology. Established by Mr. Edward L. Ryerson for special study of Greek and Roman or Oriental archaeology. Open only to students in the University of Chicago. Available for study abroad.

Senn (Nicholas) Fellowship in Surgery. Awarded by the Department of Surgery of Rush Medical College to a graduate in medicine.

Smith (Douglas) Foundation. Founded by Mr. Douglas Smith of Chicago. Appropriations are made from this fund to support various research projects, and full-time holders of these grants are designated as Douglas Smith Fellows. The number awarded and the amount of each fellowship varies according to the problems under investigation and the qualifications of the holders. Application should be made to the Advisory Committee of the Douglas Smith Foundation.

Swift (Gustavus F.) Fellowship in Chemistry. Founded by Mrs. Gustavus Swift of Chicago in 1908 as a memorial to her huband. Open to men and women who are graduate students in chemistry. Awarded for special ability in research on the nomination of the Department of Chemistry and the approval of the Chairman of the Committee on Fellowships and Scholarships.

Talcott Fellowships. Founded by Mr. William A. Talcott of Rockford, Illinois. They provide tuition fees which are reserved for graduate students, preferably for graduates of Rockford College.

Thomson-Bevan (A. D.) Fellowship in Surgery and House Surgeonship in the Presbyterian Hospital. Founded by Mr. A. D. Thomson and Professor A. D. Bevan, 1915. Awarded by the Department of Surgery of Rush Medical College to a graduate in medicine.

University Fellowships. About seventy in number. Open to men and women graduate students. Available in all departments of the University of Chicago. The University asks of each Fellow a modicum of service. Stipend, from $300 to an amount in excess of fees to cover part of the student's living expenses.

Van Liere (Helen Kimmins) Research Fellowship. Founded by Dr. Edward J. Van Liere in memory of his wife, for advanced work in the Department of Physiology.

Viol (Charles H.) Fellowship in Chemistry. Endowed through a bequest of Dr. Charles H. Viol. Available for a student studying for an advanced degree in chemistry.

Walker (Sidney, III) Scholarship. Founded by Dr. Sidney Walker, Jr. Open to men and women graduate students in physiology.

Wilder (William H., Jr.) Fellowship in Neurology. Founded by Dr. and Mrs. Wiliam H. Wilder as a memorial to their son, William H. Wilder, Jr. Awarded to a student of neurology upon nomination by the Department of Anatomy.

Wychwood Fellowship in Botany. Founded by Mrs. Charles L. Hutchinson for special research in the Department of Botany.

CHILDREN'S HOSPITAL, Cincinnati, Ohio.

Proctor Foundation Scholarships. The Proctor Foundation was established 1927, by William Cooper Proctor, for pediatric research. Original amount, $2,000,000. Present amount, $3,000,000. The Foundation is affiliated with the University of Cincinnati, and is planned to coordinate the research of the various organizations in Cincinnati and to provide ideal laboratory facilities for both the laboratory phases of the clinical investigation and for problems originating in the laboratory. There are at present two scholarships for men working in the Foundation or in the Pediatric Department of the College of Medicine of the University of Cincinnati. There are no grants or scholarships for non-residents. There is, however, provision for providing laboratory facilities for holders of research grants from other institutions.

CINCINNATI, UNIVERSITY OF, Cincinnati, Ohio.

It is understood that the stipends of these fellowships are subject to change.

Ault (L. A.) Fellowship in Surgery. Founded by Mrs. B. N. Carter. Available in this University for research in surgery. Stipend, $600 a year. Applications should be filed with the Department of Surgery, General Hospital, Cincinnati.

Baldwin Fellowships. Ten. Founded by the Francis Baldwin Estate. Open to men and women who are holders of a bachelor's degree; preference given to those who intend to become candidates for the degree of Doctor of Philosophy. Available in this University for study in science and the humanities. Stipend, $500 to $750 a year. No fellow will be permitted to accept remunerative employment, or to give instruction or assistance in any department of the University, except by permission of the Faculty, and the breaking of this rule will operate to vacate the fellowships. These fellowships have been temporarily withdrawn but it is expected they will be reestablished when finances improve.

Children's Hospital Research Foundation. Founded by Mr. William Cooper Procter for fellowships and scholarship in pediatric research at the Children's Hospital, Cincinnati. Applications should be filed with the Department of Pediatrics, General Hospital.

Christ Hospital Fellowships in Biochemistry. Two. Founded by Christ Hospital for research work in biochemistry. Open to holders of a bachelor's degree. Stipend, $750 a year each. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Davis Teaching Fellowship in Preventive Medicine. Founded by the Union Central Life Insurance Company, 1922. Open to men and women. Available in this University for research in bacteriology and preventive medicine. Stipend, $600 a year. Applications should be filed with the Department of Bacteriology and Hygiene, College of Medicine, University of Cincinnati.

Dennis (Martin) Fellowship in Leather Research. Founded by the Martin Dennis Company for research work in the Department of Leather Research. Open to holders of a bachelor's degree. Applications should be filed with the Department of Leather Research, University of Cincinnati.

Graduate Assistantships in Surgery. Eight. Established by the Department of Surgery for research work in surgery. Stipend, $350 a year each. Applications should be filed with the Department of Surgery, General Hospital, Cincinnati.

Hanna Fellowship in Physics. Founded by Mrs. Henry Hanna and Miss Mary Hanna, 1906. Open to men and women who are holders of a bachelor's degree. Available in this University for the study of physics. Stipend, $500 a year. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Hyman (David M.) Fellowship in Research Medicine. Founded by Mrs. Gertrude H. Friedlander and Mrs. Louise H. Pollak. Open to men and women who are holders of a bachelor's degree. Available in this University for the study of medicine. Applications should be filed before March 15th with the Department of Medicine, General Hospital, Cincinnati.

Hyndman (James Gilmour) Fellowship in Preventive Medicine. Founded by Mrs. Mary E. Hyndman for research in preventive medicine. Stipend, $1000 a year. Applications should be filed with the Department of Bacteriology and Hygiene, College of Medicine, University of Cincinnati.

Iglauer (Charles Arnold) Fellowship in Biochemistry. Founded by Dr. and Mrs. Samuel Iglauer for research work in biochemistry. Open to holders of a bachelor's degree. Stipend, $165 a year. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Jergens (Andrew) Fellowship in Biochemistry. Founded by the Andrew Jergens Company for research work on the properties and functions of the skin. Stipend, $1500 a year. Open to holders of a bachelor's degree. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Laws Fellowships in Pure Science. Six. Established by a bequest of Mr. Henry Laws for research work in chemistry, mathematics and physics. Open to men and women who are holders of a bachelor's degree. Stipend, $500 to $750 a year according to the qualifications and training of the applicants. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Mendenhall (George) Scholarship in Obstetrics. Established in 1921 by Mrs. Emma Mendenhall Anderson, in memory of her father. Awarded to resident in obstetrics in the Cincinnati General Hospital. Stipend, $500.

Merrell Fellowship in Biochemistry. Founded by Mr. Charles G. Merrell of the William S. Merrell Company. Open to holders of a bachelor's degree. Available in this University. Stipend, $1500 a year. The fellowship was established for the investigation of the nature of the natural cure of disease. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Moos (Henry M.) Fellowships in Internal Medicine. Two. Founded by Mrs. Jeanette Moos for research work in internal medicine. Open to holders of a bachelor's degree. Stipend, $1300 for the two. Applications should be filed before March 15th with the Department of Medicine, General Hospital, Cincinnati.

Neave Fellowship in Pediatrics. Open to men who are holders of a bachelor's degree and an M. D. degree. Course work in the Graduate School and full-time service in connection with the Cincinnati Orphan Asylum. Stipend, $600 a year. Applications should be filed with the Department of Pediatrics, General Hospital, Cincinnati.

Procter (William Cooper) Fellowship in Surgery. Founded by Mr. William Cooper Procter. Open to men who are holders of a bachelor's degree and an M. D. degree. Course work in Graduate School and full-time service in General Hospital. Stipend, $600 a year. Applications should be filed with the Department of Surgery, General Hospital, Cincinnati.

Ransohoff Fellowship in Surgery. Founded by Mrs. Joseph Ransohoff. Open to men who are holders of a bachelor's degree and an M. D. degree. Course work in Graduate School and full-time service in General Hospital. Stipend, $1000 a year. Applications should be filed with the Department of Surgery, General Hospital, Cincinnati.

Röhm and Haas Fellowship in Leather Research. Founded by the Röhm and Haas Company, Inc., for research work in the Department of Leather Research. Open to holders of a bachelor's degree. Applications should be filed with the Department of Leather Research, University of Cincinnati.

Seely Teaching Fellowship in Internal Medicine. Founded by Mrs. W. W. Seely, 1922. Open to men and women. Stipend, $1000 a year.

Appointment usually made in June. Applications should be filed with the Department of Medicine, General Hospital, Cincinnati.

Special Fellowship in Physics. Donor anonymous. Open to men and women who are holders of a bachelor's degree. Available in this University for research in physics. Stipend, $250 a year. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Taft Fellowships. Six. Founded by Mr. and Mrs. Charles Phelps Taft. Open to men and women who are holders of a bachelor's degree; preference given to those who intend to become candidates for the degree of Doctor of Philosophy. Available in this University for the study of science or the humanities. Stipend, $500 to $750 a year. *See* comment on Baldwin Fellowships which also applies here.

Taft Memorial Teaching Fellowships. Eight. Founded by the Charles Phelps Taft Memorial Fund in the Departments of Classics, Economics, English, German, History, Mathematics, Philosophy and Romance Languages. Open to men and women who are holders of a bachelor's degree. Stipend, $1000 a year each. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

University Fellowships in Pediatrics. Four. Founded for Assistant Residents in Pediatrics who are candidates for the degree of Master of Science for work in pediatrics in the Graduate School. Stipend, $300 a year each. Applications should be filed with the Department of Pediatrics, General Hospital, Cincinnati.

University Fellowship in Surgery. Established by the Department of Surgery to be awarded to the Resident Surgeon in the Cincinnati General Hospital. Stipend, $1000 a year. Applications should be filed with the Department of Surgery, General Hospital, Cincinnati.

University Scholarships. Twelve. Open to men and women who are holders of a bachelor's degree. Available in this University for general scientific study. Stipend, tuition and laboratory fees. Applications should be filed before March 15th with the Secretary of the Graduate School. Special application form furnished.

Wyler (Jesse S.) Scholarship in Ophthalmology. Established by Mrs. Isaac A. Wyler in memory of her son. Awarded to a resident in ophthalmology in the Cincinnati General Hospital. Stipend, $250.

CLARK UNIVERSITY, Worcester, Mass.

Applications should be filed by March 1st with Secretary of the Graduate Board. Special application form furnished.

Fellowships. Open to men and women with a master's degree or equivalent. Available in this University for research in geography and psychology, biology, history and international relations, economics and sociology, chemistry and physics. Stipend, $200 to $400 a year, including tuition.

Scholarships. Open to men and women with a bachelor's degree. Available in this University for study in physics, geography, psychology, chemistry, biology, history and international relations, economics and sociology. Stipend, $100 to $400 a year.

University Fellowships. Open to men and women of advanced graduate standing. Available in this University for study of geography, psychology, biology, history and international relations, economics and sociology, chemistry and physics. Stipend, board, room and tuition.

CLAY PRODUCTS ASSOCIATION, 111 West Washington St., Chicago, Ill.

Fellowship at the University of Illinois on the subject of materials for the making of sewer pipe joints.

CLEVELAND CLINIC FOUNDATION, Cleveland, Ohio.

The Foundation promotes research in biophysics, biochemistry, endocrinology, urology and problems pertaining to surgery and to internal medicine. For work in any of these, Fellows may be appointed as need arises. Available funds vary according to the requirements of the work done. There are two established fellowships:

Belcher (George W.) Fellowship in Urological Research.

McBride (Sarah Tod) Fellowship in Biophysics.

COE COLLEGE, Cedar Rapids, Iowa.

Graduate Associate Fellowships. Two to six. Established in 1910 on the following plan: (1) The head of each department is authorized to select yearly from among the graduates of the College one student, to be known as the graduate associate for the department. (2) If it be the student's desire he may, without charge, register and pursue a course for the master's degree in the department of his graduate work. (3) The graduate associate is required to render to the department such service as the head of the department may consider best adapted to give him didactic review, but not in amount sufficient to interfere with his studies. (4) The head of the department is expected to take his graduate associate into personal collaboration in his own special line of study and to adopt him, so to speak, as a private assistant and fellow student along the lines of his advanced study. Open to men and women. Stipend, tuition.

COFFIN (CHARLES A.) FOUNDATION, Schenectady, N. Y.

Coffin (Charles A.) Fellowships. Six to ten. Founded by General Electric Company, 1922. Open to men who are graduates of universities, colleges and technical schools in the United States. Available in any American university or abroad for research in electricity, physics and physical chemistry. Stipend, $500 (minimum) a year. Applications should be filed by February 15th with the Secretary. Special application form furnished.

COLGATE UNIVERSITY, Hamilton, N. Y.

Sanders (Henry M.) Scholarship. Founded by bequest of Henry M. Sanders. Ordinarily awarded to a senior as recognition of outstanding excellence in college work of the preceding three years at Colgate, but may be awarded to a member of the graduating class or to a recent graduate for the purpose of enabling him to pursue graduate studies at some leading American or foreign university. Open to men only. Stipend, $400 (1933-34).

COLORADO, UNIVERSITY OF, Boulder, Colo.

Applications should be filed before March 1st with the Dean of the Graduate School. Special application form furnished.

Graduate Scholarships. Forty. Awarded to graduate students who need financial help and show promise of success in advanced work. Stipend, tuition and major department fees.

Research Fellowships. Ten. Founded by the University, 1922. Open to men and women who have graduated and had some previous training in graduate study and research, and have in some way proved their fitness for advanced work. Available in this University for general scientific study. Stipend, $400 a year, plus tuition and major department fees. Not over three hours per week required in service.

University Fellowships. Ten. Founded by the University, 1922. Open to men and women who are recent graduates of promise and as yet untried in advanced work and research. Available in this University for general scientific study. Stipend, $200 a year plus tuition and any major department fees. Not over three hours per week required in service.

COLORADO, UNIVERSITY OF, SCHOOL OF MEDICINE, 4200 East Ninth Ave., Denver, Colo.

Child Research Council of Denver. Established 1922 as Selmene Winter Foundation; incorporated 1927 as Child Research Council through a grant from the Commonwealth Fund and gifts from citizens of Denver. The purpose is to study child development from birth through adolescence. Annually available (at present time), $42,000. From twelve to fifteen fellows are employed in the work. Fellows are selected by the full time Director upon approval by the Board of Control.

Psychiatric Fellowships. Six. Established by the Commonwealth Fund, New York, N. Y., for graduate work in psychiatry. Open to men with an M. D. degree and one year of general interneship, as well as an interest in psychiatry. Applicants must be between 24 and 35 years of age. Available for study in this University only. Stipend, $1500 to $1800 a year. Applications should be filed by January 1st on special form furnished by Head of Department of Psychiatry.

COLORADO COLLEGE, Colorado Springs, Colo.

Teaching Fellowships. Twenty. Established 1934. Open to men and women with an A. B. degree, high scholarship and interest in teaching, for study in this College. Applications may be filed at any time. The twenty fellowships are for all departments of the College, with probably six or seven for work in science.

COLUMBIA UNIVERSITY, New York, N. Y.

Adams (Ernest Kempton) Research Fellowship. Founded by Edward Dean Adams, 1904. Open to men and women. Appointment is made from among the teaching staff, alumni or students of the University, or from among the distinguished physicists of the United States or foreign countries. Available in any American university or abroad for research in physical sciences or their practical application. Stipend, about $1250.

Barnard Fellowship for Encouraging Scientific Research. Awarded every third year. Founded by President Barnard, 1889. Open to men and women, who are appointed upon the joint vote of the Faculties of Columbia College, of Engineering and of Pure Science. Available in this University for research in physical science. Stipend, about $1500.

Blumenthal (George, Jr.) Fellowships. Founded 1909. Open to men and women who are nominated by the Medical Faculty. Available, under the supervision of the Medical Faculty, for study in medicine and surgery. Stipend, about $1000.

Boring Fellowship in Architecture. Awarded every third year. Founded by Mr. Edward C. Moore, Jr., 1922. Open to men and women who are graduates of the School of Architecture, within three years following their graduation, and to all matriculated students in the School who have completed the requirements for the thesis as fixed by the Faculty of the School. Available for the study of architecture abroad. Stipend, about $900.

Bridgham (Samuel Willard) Fellowship. Founded by Mrs. Fanny Bridgham, 1915. Open to men, on recommendation of the Faculty of Engineering. Available in this University for general scientific study. Stipend, about $1000.

Clark Scholarship. Founded by Alonzo Clark, M. D., 1894. Open to men and women. Awarded to such person as the Faculty of the College of Physicians and Surgeons may appoint, who shall devote himself to study under their guidance with the special purpose of discovering new facts in medical science. Stipend, about $900.

Curtis University Scholarships. Two. Open to women students under the Faculties of Political Science, Philosophy and Pure Science. Stipend, $300.

Cutting (William Bayard) Traveling Fellowships. Number varies. Founded by Mrs. W. Bayard Cutting and her children, 1913. Open to men who have been in residence as graduate students and candidates for higher degree under the Faculties of Political Science, Philosophy or Pure Science, for at least one year and to graduates of Columbia University in law, medicine, engineering or architecture; not more than two granted in one year to graduating seniors. Preference to be given to candidates of American parentage. Available in any American university or abroad. Stipend, about $2000 a year. Applications should be filed by April 1st with the Office of the Secretary. Special application form furnished.

DuBois (Abram) Fellowship. Founded by William A., Matthew B. and Katherine DuBois, 1910. Open to men and women who are graduates of the School of Medicine. Available for research in diseases of the eye. Stipend, about $900.

Duror (Caroline) Memorial Fellowship. Founded 1912, the gift of an anonymous donor. Open to graduates of Barnard College to pursue graduate study in natural sciences or mathematics. Available in this University or in any other university or college of approved standing. Stipend, about $600. This fellowship is not to be applied for but is awarded each year as an academic honor.

Ellis (George W.) Fellowships. Two. Founded by George W. Ellis, 1930. Open to men and women graduates of any of the colleges of recognized rank in the state of Vermont to pursue studies under any one of the graduate schools maintained by the University Corporation. Stipend, $1600. Special application form furnished.

Emmons Geological Fellowship. Awarded usually every second year. Founded by Emmons Memorial Fund Committee, 1913. Available in any American university for research in geology. Stipend prescribed by the Committee in each case. Application should be filed by March with the Office of the Secretary.

Evans (Henry) Traveling Fellowship. Founded by Mrs. Henry Evans, 1928. Open to graduates of Columbia College who seem to be best qualified to make permanent contributions of value to architecture, letters, science or law. Available for studies either in foreign countries or in other institutions or places in the United States. Stipend, about $1500. Applications should be filed by April 1st with the Office of the Secretary.

Ferguson Fellowship. Awarded every second year. Founded by William C. Ferguson, 1921. Open to men and women. The holder of the fellowship shall carry on investigation and research in synthetic drugs and medicines under the direction of the Department of Chemistry. Stipend, about $1000.

Gies (William J.) Fellowship. Founded by Dr. William J. Gies, 1923. Open to students who have prerequisites for admission to graduate study in biological chemistry. The stipend will be fixed at the time of the award.

Goldschmidt (Samuel Anthony) Fellowship in Applied Chemistry. Founded by George B. Goldschmidt, 1908. Open to graduates of colleges or scientific schools who show themselves especially fitted to pursue courses of higher study. Stipend, about $1200.

Gottsberger Fellowship. Founded by Ellen Josephine Banker, 1904. Open to men who, having first taken a degree in Columbia College, have been for not less than two years resident graduate students at Columbia University. Available in this University or abroad (with consent of department in charge of major subject) for general scientific study. Stipend, about $1400.

Hendrick (Elwood) Fellowship in Chemical Engineering. Founded by Mrs. Elwood Hendrick and her daughter. Open to graduate students in Chemical Engineering in this University. Stipend, about $1200.

Holt (L. Emmett) Fellowship in Diseases of Children. Founded by Dr. L. Emmett Holt, 1925. Open to students of the graduating class of the College of Physicians and Surgeons, Columbia University, or to graduates of not more than two years standing. Available in this country or abroad to prosecute the study of the diseases of children under the general guidance of the nominators of the fellowship. Stipend, about $1200.

James (Walter Belknap) Fellowship in Medicine. Founded by Dr. Walter B. James, 1927. Open to men and women who are graduates in medicine to pursue advanced studies under the direction of the Faculty of Medicine. Available in this University or elsewhere with the approval of the Faculty of Medicine. Stipend, about $2500.

Kempt (James Furman) Fellowship in Geology. Founded 1924, the gift of an anonymous donor. Available for advanced study in geology. Stipend, about $1000.

Koplik Children's Fellowship. Awarded every second year. Founded by Henry Koplik, 1928. Open to physicians, under thirty years of age, who have shown special aptitude for original work in the investigation of the diseases of children. Available in this University or, with the approval of the Faculty of Medicine, elsewhere. Stipend, about $2000.

Lydig Fellowship. Founded by Hannah M. Lydig, 1931. Open to graduate men and women students to pursue studies or researches under the Faculties of Political Science, Philosophy or Pure Science. Available in this University or abroad. Stipend, about $2000.

McKim Fellowship in Architecture. Awarded every third year. Founded by Charles F. McKim, 1889. Open to men and women who are graduates of the School of Architecture, within three years following their graduation, and to all matriculated students in that School who have completed the requirements for the thesis as fixed by the Faculty of the School. Available abroad for the study of architecture. Stipend, about $2200.

Mitchell (William) Fellowship. Founded by Benjamin D. Silliman, 1908. Open to men who are graduates of Columbia College. Available for advanced study in letters or science. Stipend, about $500. Applications should be filed by April 1st with the Office of the Secretary.

Perkins Fellowship in Architecture. Awarded every third year. Founded by Willard B. Perkins, 1898. Open to men and women who are graduates of the School of Architecture, within the three years following their graduation and to all matriculated students in that School who have completed the requirements for the thesis as fixed by the Faculty of the School. Available abroad for the study of architecture. Stipend, about $800.

Plaut (Isaac) Fellowship. Founded by Albert Plaut. Open to men and women. Awarded to that Bachelor of Science in Pharmacy of the College of Pharmacy, who shall have shown among the members of his class during his course of study the greatest taste and aptitude for original investigation. Available abroad for the study of pharmacy. Stipend, about $1000.

Proudfit (Maria McLean) Fellowship. Awarded every fourth year, the term to be for two years. Founded by Alexander Moncrief Proudfit, 1899. Open to sons of native-born American parents. The holder of the fellowship shall remain unmarried during its tenure. Available in this University, unless the Faculty of Medicine approves elsewhere, for the study of medicine. Stipend, about $1500 a year.

Research Fellowships in Medicine. Two. Available in this University. Stipend, $1500.

Roberts (Lydia C.) Graduate Fellowships. Number varies. Founded by Mrs. Lydia C. Chamberlain, 1920. Open to persons of the Caucasian race, of either sex, born in the state of Iowa, who have been graduated from a college or university located in the state of Iowa. No fellow so appointed shall pursue the studies of law, medicine, dentistry, veterinary medicine or theology, except in so far as instruction in such subjects is a part of the program of study leading to a degree other than a professional degree in any one of the subjects named. Stipend, $850. Special application form furnished.

Roberts (Lydia C.) Traveling Fellowship. Founded by Mrs. Lydia C. Chamberlain, 1920. Open to men and women who have been Lydia C. Roberts fellows. Available abroad. Stipend, about $1200. Special application form furnished.

Schermerhorn Fellowship in Architecture. Awarded every third year. Founded by the Trustees, 1889. Open to men and women who are graduates of the School of Architecture, within three years following their graduation and to all matriculated students in that School who have completed the requirements fixed by the Faculty of the School. Available abroad for the study of architecture. Stipend, about $1800.

Trowbridge (William Petit) Fellowship in Engineering. Founded by Alumni Association of the School of Mines, 1893. Open to men. Fellow recommended by a Committee, consisting of President of the University and Heads of Departments of Mining, Civil, Mechanical and Electrical Engineering. Stipend, about $600.

Tyndall Fellowship for Encouragement of Research in Physics. Awarded every second and third year in a cycle of three years. Founded by Professor John Tyndall, 1885. Open to men and women who are graduates of this University and to students in the University who are not necesarily candidates for a degree. Available in this or any other American university or abroad. Stipend, about $900.

University Fellowships. Twenty-six, eighteen under the Faculties of Political Science, Philosophy and Pure Science, five in law, one in architecture and two in business. Open to men and women graduates of colleges and scientific schools, who show themselves especially fitted to pursue courses of higher study and original investigation. Stipend, $1500.

University Scholarships. Four under the Faculties of Political Science, Philosophy and Pure Science. Open to men and women graduates of colleges and scientific schools of approved standing who are candidates for higher degrees and who are less than thirty years of age. Stipend, $300.

COMMONWEALTH FUND, 41 East 57th St., New York, N. Y.

Commonwealth Fund Fellowships. Twenty-seven. Founded by Mrs. Stephen V. Harkness, 1918. Twenty fellowships open to unmarried men and women not more than thirty years of age, domiciled in England, Scotland, Wales and Ireland, and graduates of recognized universities therein; two to unmarried men and women not more than thirty years of age, graduates of recognized Colonial universities studying at a British university; five to men not more than thirty-five years of age, graduates of British or Colonial universities who hold appointments in the British Colonial Service. No limitation on subject of study. Fellowships are for two years; one quarter may be renewed for a third year. Fellows must undertake on the termination of the Fellowship to return to Great Britain or some other part of the British Empire and to reside there for a period of not less than two years. Available in any university which is a member of the Association of American Universities or the equivalent. Applications should be filed by February 1st with Richard H. Simpson, Secretary, 35 Portman Square, London, W. 1, England.

CORNELL UNIVERSITY, Ithaca, N. Y.

Each of the following fellowships, not including the Special Temporary Fellowships, unless otherwise noted, has an annual value of $400. Each of the scholarships, unless otherwise noted, has an annual value of $200. Some of the fellows and scholars are also exempt from tuition. Fellowships and scholarships are open to men and women who have already received a first degree at a college which offers training equivalent to that at Cornell. They are available in this University only unless otherwise stated. A fellow or scholar may at the discretion of the professors in the field concerned, be called upon for assistance to the extent of six clock hours per week. Applications should be filed on or before March 15th with the Office of the Graduate School. Special application form furnished.

American Dry Milk Institute Fellowship. Special temporary fellowship. Information in regard to it may be obtained from the Department of Animal Husbandry.

Brooks (Erastus) Fellowship in Mathematics.

Earle (Charles Bull) Memorial Fellowship in Mechanical and Electrical Engineering.

Graduate Scholarships. There are graduate scholarships in: animal biology, archaeology, architecture, botany, chemistry, civil engineering, geology, history, Latin and Greek, mathematics, physics and veterinary medicine. The graduate scholarship in architecture grants only free tuition.

Kraco Fellowship. Special temporary fellowship. Information in regard to it may be obtained from the Department of Poultry Husbandry.

Lily Disease Investigation Fellowship. Special temporary fellowship. Information in regard to it may be obtained from the Department of Plant Pathology.

Long (Eleanor Tatum) Scholarship in Structural Geology. Established 1924.

McGraw Fellowship in Civil Engineering.

McMullen (John) Research Scholarships. Seven. Established 1923, by John McMullen. Open to men with engineering degree, for study in this University. Appointments made only from the staff of Cornell University. Stipend, $1350 to $1890 a year.

Meyer (Edgar J.) Memorial Fellowship in Engineering Research.

Nassau County Farm Bureau Association Fellowship. Special temporary fellowship. Information in regard to it may be obtained from the Department of Plant Pathology.

New York Florists' Club Fellowship for the Investigation of Diseases of Cyclamens and Other Potted Plants. Special temporary fellowship. Information in regard to it may be obtained from the Department of Plant Pathology.

New York Florists' Club Fellowship for the Investigation of Diseases of Roses Grown under Glass. Special temporary fellowship. Information in regard to it may be obtained from the Department of Plant Pathology.

Niagara Sprayer and Chemical Company Fellowhip for the Testing and Development of Fungicides. Special temporary fellowship. Information concerning it may be obtained from the Department of Plant Pathology.

President White Fellowship in Physics.

Rogers Seed Company Fellowship. Special temporary fellowship. Information in regard to it may be obtained from the Department of Plant Pathology.

Sage Fellowship in Chemistry.

Sage (Susan Linn) Fellowship in Psychology.

Sage (Susan Linn) Scholarship in Psychology.

Schuyler Fellowship in Animal Biology.

Sibley Fellowship in Mechanical and Electrical Engineering.

Smith (Anna Cora) Fellowship in Home Economics. About $500.

Smith (Clinton Dewitt) Fellowship in Agriculture. About $500.

Smith (Goldwin) Fellowship in Botany, Geology, or Physical Geography.

Standard Brands Fellowship. Established for 1934-35, to be awarded in the Department of Hotel Administration for a study of the effect of coffee on human behavior. Stipend, $750 a year.

Staten Island Growers' Fellowship. Special temporary fellowship. Information in regard to it may be obtained from the Department of Plant Pathology.

Thompkins (Daniel J.) Fellowship Fund. Gift under the will of Mrs. Ada Parsons Thompkins as a foundation for a post-graduate fellowship in medicine and surgery in the Medical School. $1500 a year.

United States Metals Refining Company Fellowship. Awarded to a student in the Department of Floriculture and Ornamental Horticulture, for study of the effects of copper containers for plants and for cut flowers. Stipend, $250 a year.

University Fellowship in Agriculture.

University Fellowship in Architecture.

CROP PROTECTION INSTITUTE, 2101 Constitution Ave., N. W., Washington, D. C.

The Institute conducts research work, particularly as it may be applied to the protection of crops. Special funds are sought for this purpose, from individuals or industrial companies. The Institute has entire control of the investigations. Projects may extend from a few months to several years. Stipends of fellows vary from $50 to $300 per month, according to the qualifications of the fellows and the time they give to the work. Appointments are usually made from chosen men and are not subject to competitive applications. The work is done at recognized institutions, under the direction of regular professors, with the cooperation of special committees of the Institute.

DARTMOUTH COLLEGE, Hanover, N. H.

Applications should be filed not later than March 1st with the Committee on Fellowships.

Barker (Fred Demerritte) Fellowship. Founded by Augustine V. Barker in memory of his son, Lt. Fred Barker. The recipient of this fellowship shall be selected on a basis similar to that on which the Rhodes Scholarships are awarded, viz.: 1. Qualities of manhood, force of character, and leadership; 2. literary and scholastic ability and attainments; 3. physical vigor, as shown by participation in outdoor sports or in other ways. Stipend, $900 a year.

Campbell (Richard Crawford, Jr.) Fellowship. Founded 1919 by Mrs. R. C. Campbell for scientific or other graduate study. Open to recent graduates of the College. Stipend, $900 a year.

Chamberlin (George E.) Fellowship. Founded by Mrs. Adelia D. McAlpine in memory of George Ephraim Chamberlin. Stipend, $900 a year.

Miller (Charles O., Jr.) Memorial Fellowship. Founded by Mrs. Mary Elizabeth White Miller in memory of her husband. Conditions of award are the same as those for the Barker Fellowship. Stipend, $900 a year.

Parker (Henry Elijah) Fellowship. Founded by Professor Henry Parker. Stipend, $900 a year.

Richardson (James B.) Fellowship. Founded by James B. Richardson and supplemented by a bequest from Miss Catherine Richardson. Conditions of award are the same as those for the Barker Fellowship. Stipend, $900 a year.

Tucker (William Jewett) Fellowship. Offered by the alumni of the College through the medium of the Dartmouth College Alumni Fund on the Tucker Foundation to exceptional men among the graduates of the College. The aim is to secure the services of those among its graduates who may be best qualified for college teaching. Hence the holder shall be ready, if required, at the end of his term, to serve the college as an instructor. Holder chosen by the President. Stipend, usually $1000 a year.

DUKE UNIVERSITY, Durham, N. C.

Duke (Angier B.) Memorial Fellowship. Founded 1926 by The Angier B. Duke Memorial, Inc. May be awarded for scientific study or in any other department or field in which the Graduate School offers instruction. Open to men and women who are graduates of a standard college who have had at least one year of post graduate work and are candidates for the Ph. D. degree. Stipend, $1000 annually. Applications must be filed on special application form before March 15th of each year and sent to the Dean of the Graduate School.

Graduate Assistants. Forty-eight in 1933-34; 26 in the sciences. Open to men and women who are graduates of standard colleges, for study in this University. Stipend, $300 to $650 a year. Applications should be filed before March 15th on special form furnished by the Dean of the Graduate School.

Graduate Scholarships. Twenty-four in 1933-34. Not assigned to departments, but may be awarded in any department in which graduate instruction is offered. Open to men and women who are graduates of standard colleges, for study in this University. Special permission is occasionally granted for study abroad. Stipend, seventeen at $400; seven at $350 a year. Applications should be filed before March 15th on special form furnished by the Dean of the Graduate School.

University Fellowships. Twenty-seven in 1933-34. Not definitely allocated, but may be awarded in any field in which graduate instruction is offered. Open to men and women who are graduates from standard colleges, and usually have had one year of post graduate work. Stipend, $600 to $650 (1933-34). Applications should be filed before March 15th on special form furnished by the Dean of the Graduate School.

DU PONT DE NEMOURS AND COMPANY, E. I., Wilmington, Del.

National Fellowship at Johns Hopkins University. Stipend, $1000. Subject to the rules and regulations of the National Fellowship Plan as inaugurated at Johns Hopkins University.

The following awards are made to the respective institutions and the individual recipients are selected according to their rules and regulations. These are not considered as du Pont fellowships but as grants made by the various departments and subsidiaries, usually for a specific study.

Departmental Grant to Alabama Polytechnic Institute, for the study of reactions between chemical fertilizers and the soil. $750 a year. Sponsored by the Ammonia Department of the du Pont Company.

Departmental Grant to the Institute of Paper Chemistry. $1000 a year. Sponsored by the Organic Chemicals Department of the du Pont Company.

Departmental Grant to Ohio State University, for the study of reactions between chemical fertilizers and the soil. $750 a year. Sponsored by the Ammonia Department of the du Pont Company.

Departmental Grant to the University of Notre Dame, for the study of chemistry. $750 a year. Sponsored by the Organic Chemicals Department of the du Pont Company.

ELECTROCHEMICAL SOCIETY, THE, Columbia University, New York, N. Y.

Weston (Edward) Fellowship. Founded by Dr. Edward Weston, of Newark, N. J., 1928. Open to men and women, of any citizenship, race or residence, who have completed an undergraduate course in some college, university or technical institute, and are less than thirty years of age at the time of award. Available in an American university or abroad, for research in electrochemistry or its applications. Award made for term of one year, but the Board of Directors shall have the option in its discretion of continuing the award to the same Fellow. Stipend, about $1000 a year. Application should be filed with the Secretary of the Society, Colin G. Fink. Special application form furnished. Award made on March 1st.

EMORY UNIVERSITY, Emory University, Ga.

Applications should be filed by March 1st with Dean of Graduate School, Emory University, Ga. Special application form furnished.

Bio-chemistry Fellowships. Two. Open to men and women with a bachelor's degree. Available only in Emory University. Stipend, $500 a year.

Graduate School Fellowships and Scholarships. Ten. Founded 1919. Open to men and women with a bachelor's degree for study in this University. Stipend, $125 to $500 a year.

Social Science Research Fellowships. Two. Founded 1931. Open to men and women with a bachelor's degree for study in this University. Stipend, $225 to $500 a year.

Turner Scholarships. Two. Founded 1928, by Alfred C. Turner. Open to men and women with a bachelor's degree for study in this University. Stipend, $225 to $300 a year.

FLORIDA, UNIVERSITY OF, Gainesville, Fla.

The following fellowships and assistantships are open only to men. The educational requirements are a satisfactory bachelor's degree and foundation in the subject in which the fellowship is held. They are available for study in this University only. Applications should be filed by May 1st with the Professor whose name follows the entry. Special application form is furnished only for the Fellowship in Chemistry.

Graduate Assistantships.

Agricultural Economics. Stipend, $450 a year. Prof. J. E. Turlington.

Architecture and Allied Arts. Stipend, $450 a year. Prof. Rudolph Weaver.

Biology and Geology. Two. Stipend, $360 a year. Prof. J. S. Rogers.

Chemistry. Six. Stipend, $450 a year. Dean T. R. Leigh.

Civil Engineering. Stipend, $360 a year. Prof. P. L. Reed.

Entomology and Plant Pathology. Stipend, $450. Prof. J. T. Creighton.

Horticulture. Stipend, $450 a year. Prof. W. L. Floyd.

Mechanical Engineering. Stipend, $360 a year. Prof. Melvin Price.

Pharmacognosy and Pharmacology. Two. Stipend, $450 a year. Prof. B. V. Christensen.

Pharmacy. Two. Stipend, $450 a year. Prof. W. J. Husa.

Physics. Three. Stipend, $360 a year. One, part time. Stipend, $120 a year. Prof. R. C. Williamson.

Psychology. Stipend, $360 a year. Prof. E. D. Hinckley.

Graduate Scholarships. Ten. Stipend, $250 a year. Dean J. N. Anderson. Application should be filed not later than March 15th.

FORDHAM UNIVERSITY, New York, N. Y.

Graduate Fellowships. Seven. Founded 1921, for the study of chemistry. Open to men with a bachelor's degree with a minimum of thirty-six points in chemistry. Available only in this University. Stipend, $600 to $1400 a year. Applications should be filed before February 1st with Head of Department of Chemistry.

GEORGE WASHINGTON UNIVERSITY, Washington, D. C.

King (Isabella Osborn) Research Fellowship. Founded 1928, by Isabella Osborn King, for general scientific study in biology. Open to men and women who are graduate students and acceptable to the Graduate Council. Available only in this University. Stipend, up to $1200 a year. Applications should be filed on or before March 1st on special blanks furnished by the Chairman of the Graduate Council of the University. The fellowship is usually granted to a graduate of this institution.

Sanders (Thomas Bradford) Fellowships. Eleven. Founded 1930, by Addie Sanders. Three of these are allotted to chemistry, four to physics, two to psychology, one to history and one to economics. The same conditions of award hold as in the case of the Isabella Osborn King Fellowship given above. Stipend, up to $600 and tuition.

GOUCHER COLLEGE, Baltimore, Md.

Dean Van Meter Alumnae Fellowship. One every other year. Founded by Alumnae Association of Goucher College, 1917. Open to women who are graduates of Goucher and have been members of the Alumnae Association of Goucher College through a contribution to the Alumnae Fund for the year in which the application is made and the year immediately preceding. Available in any American university or abroad for research in science or non-science branches. Stipend, $1000 a year. Applications should be filed by March 1st. Special application form furnished. The application must be accompanied by evidence of the special work done after graduation and addressed to the Chairman of the Fellowship Committee of the Faculty of Goucher College.

JOHN SIMON GUGGENHEIM MEMORIAL FOUNDATION, 551 Fifth Ave., New York, N. Y.

Guggenheim (John Simon) Memorial Fellowships. Approximately fifty. Founded by former United States Senator and Mrs. Simon Guggenheim, 1925. Open to men and women of high intellectual and personal qualifications, who have already demonstrated unusual capacity for productive scholarship or unusual creative ability. Applicants may be married or unmarried, not younger than twenty-five nor older than thirty-five (though no hard or fast age limits are prescribed), citizens of the United States, irrespective of race, color or creed. In exceptional cases, the fellowships are open to permanent residents of the United States who are not citizens. Available for research in any field of knowledge and for creative work in any of the fine arts, including music. Normal stipend, $2000 a year. The tenure of the fellowship will be adjusted to the purpose and scope of the study of each individual, although it will ordinarily be one year. In special cases terms shorter than one year will be granted. Members of the teaching profession who have received sabbatical leave on full or part salary will be eligible for appointment. Applications should be filed with the Secretary, Henry Allen Moe, on or before November 1st. Final selections made in March. Special application form furnished.

Latin American Fellowships. Founded by Hon. Simon Guggenheim, 1929. Open to men and women, without distinction of race, color or creed. It is expected that candidates will generally be graduates of universities or professional schools, or persons who in other respects have taken advantage of the educational facilities available in their own countries in their special fields of study. To 1933, the countries included in the plan are Argentina, Chile, Cuba and Mexico; also available to Porto Ricans. Available for independent research and also for advanced training in the various professions. No restriction in choice of university or other place of study within the United States. Normal stipend, $2000 for twelve months plus travel allowance proportionate to the distances to be covered. Applications should be filed with the Secretary on or before January 1st. Final selections made in June. Special application form furnished.

HAMILTON COLLEGE, Clinton, N. Y.

Root Fellowship in Science. Founded by Elihu Root in 1894. Open to men who are members of the senior class and have shown special aptitude for research in one or more of the departments of science. Available in some American or European university approved by the Faculty, for a year of graduate study in science. Stipend, $1000 a year. No applications received; awarded by the Trustees on recommendation of the Faculty.

HARVARD UNIVERSITY, Cambridge, Mass.

In general the following conditions apply to the fellowships listed below: In making resident appointments preference is usually, though not always, given to those who have given evidence of qualifications at the University. Non-resident appointments, however, are only for graduates of some department of the University or for students who have been there for some time. Appointments are made for one year renewable for a second year, but never for more than the third year. Tuition is paid out of stipends except by non-resident holders of fellowships. Women are not eligible for appointment. The following abbreviations are used to show in which schools of the University the fellowships may be assigned, according to conditions:

Arch.—Faculty of Architecture.
Den.—Dental School
Eng.—Engineering School.
Gr.—Graduate School of Arts and Sciences.
Med.—Medical School.
Mus.—Museum of Comparative Zoology.
Pub. H.—School of Public Health.

Ames (Anna C.) Scholarship. (Gr.) Founded by Professor Oakes Ames. Available for research in applied biology. Recipient, if a zoologist, is required to take at least one of the courses in botany offered by the University; if a botanist, at least one course in zoology. Stipend, $725 a year.

Ames (Anna C.) Tuition Scholarship. (Gr.) Available for research in applied biology. Stipend, $400 a year.

Appleton (Julia Amory) Traveling Fellowship in Architecture. (Arch.) Two. Founded by Mr. Charles F. McKim, of New York. Ordinarily awarded in alternate years to masters in architecture of Harvard University not over thirty years of age on the first day of July of the year of the appointment. Stipend, $2800 a year.

Atkins Fellowships. (Mus.) Two scholarships are established each year for students of applied biology who wish to work at the Cuban Station. Stipend, $300 a year.

Austin (Edward) Fellowships. (Gr.) Four. Founded by Edward Austin, 1900. Available for graduate study in the arts and sciences. Stipend, $675 a year.

Austin Fellowships in Medicine. (Med.) Four. Founded from the income of the Edward Austin Fund. Stipend, $900 a year.

Austin Scholarships in Architecture. (Arch.) Two. Founded from the income of the Edward Austin Fund, 1902. Stipend, $400 a year.

Austin Scholarship in Landscape Architecture. (Arch.) Founded from the income of the Edward Austin Fund, 1902. Stipend, $400 a year.

Austin Teaching Fellowships. (Gr.) About thirteen. Founded by Edward Austin, 1899. Half-time graduate work in arts and sciences; half-time teaching. Stipend, $1000 a year.

Barringer (Edward M.) Scholarship No. 1. (Med.) Preference: Students in the fourth class. Stipend, $300 a year.

Barringer (Edward M.) Scholarship No. 2. (Med.) Preference: Students in the fourth class. Stipend, $200 a year.

Bartlett (Gordon) Scholarship. (Med.) Founded by Mr. and Mrs. Donald Gordon, in memory of their nephew, Gordon Bartlett, killed in the World War. Open to undergraduates or graduates of the Harvard Medical School, preference being given to graduates of Dartmouth. Usually divided between two men. Stipend, $450 a year.

Bartlett (Matthew and Mary E.) Scholarship. (Med.) Founded by Miss Fannie Bartlett, 1916. Stipend, $500 a year.

Billings (Lucius F.) Scholarship. (Med.) Founded by Mr. L. F. Billings. May be divided between two or more students. Stipend, $250 a year.

Bliss Scholarships. (Gr.) Founded by Mrs. William H. Bliss, of New York, 1917. The income of $1100 is to be applied to the establishment and support of scholarships in the Division of Forestry. The award of these scholarships is made by the Faculty of the Bussey Institution.

Bradford (Edward Hickling) Fellowship. (Med.) Founded by anonymous donor, 1918. Available for medical research or instruction separately or in connection with any other foundation, in such a manner as may be prescribed. Stipend, $1375 a year. Applications must be made to the Dean on or before May 1st.

Bright Scholarships (Gr.) Five. Founded by Jonathan Brown Bright. Preference: Descendants of Henry Bright, Jr., of Watertown, Mass., who bear the name of Bright. Open to students registered in any department of the University. Stipend, $500 a year. Applications from students registered in the Graduate Departments of the University should be made to the Chairman of the Committee on General Scholarships and on the Sheldon Fund.

Browne (John White) Scholarship. (Med.) Founded by Mrs. Francis B. Greene. Open to a student of unusual promise to pursue research investigations for one year at the Harvard Medical School or elsewhere. Stipend, $1050 a year.

Buckley (Daniel A.) Scholarships. Several. Founded by Daniel A. Buckley, 1907. Open to graduates of the Cambridge public schools. Applications from students registered in the Graduate Departments of the University should be made to the Chairman of the Committee on General Scholarships and on the Sheldon Fund.

Bullard Fellowships. (Med.) Founded by William Story Bullard, 1891, in memory of three physicians distinguished for their honorable personal character and their professional services in this community:

GEORGE CHEYNE SHATTUCK MEMORIAL FELLOWSHIP. Stipend, $350 a year.

CHARLES ELIOT WARE MEMORIAL FELLOWSHIP. Stipend, $350 a year.

JOHN WARE MEMORIAL FELLOWSHIP. Stipend, $350 a year.

Any one or all of these fellowships may be paid to any student or member of the medical profession appointed to make such original investigations in medical science as will be most useful to the profession and community. Holders must do throughout the academic year the equivalent of at least ten hours work a week and make a report thereon.

Burton (Casper Henry, Jr.) Scholarship. Founded by Mr. and Mrs. Burton, 1922. Available in any department of the University for graduate study. Nomination is made by Reverend Spence Burton and William Greenough Wendell. Stipend, $300 a year.

Cabot (Arthur Tracy) Fellowship. (Med.) Founded by Mr. and Mrs. Frederick C. Shattuck in memory of Arthur Tracy Cabot. Open to students of surgery. Ordinarily the incumbent may not engage in active practice, but is to devote himself to the advancement of surgery in the United States or elsewhere. The nomination to this Fellowship is by preference to be made by the Moseley Professor of Surgery. Stipend, $1400 a year.

Cabot (James Jackson) Fellowship. (Med.) Founded by Arthur T. Cabot, Samuel Cabot and Guy C. Cabot. The income is to be used to aid and encourage practical work in scientific medicine. Stipend, $800 a year.

Chapman (Victor Emmanuel) Memorial Fellowship. Founded by several donors, 1917. Open to French youths nominated by a committee of French scholars for graduate study in any department of the University. Stipend, $1575 a year. Applications should be filed with Professor Emile Legouis, University of Paris.

Cheever (David Williams) Scholarship. (Med.) Founded by David Williams Cheever, 1889. Available to a first-year student after three months' study in the school. Stipend, $375 a year.

Choate (Joseph Hodges) Memorial Fellowship. Founded by the Harvard Club of New York City, 1919. Open to a British subject from the University of Cambridge for graduate study in any department of this University. Stipend, $2000 a year. Applications should be filed with Vice-Chancellor of the University of Cambridge, England.

Corey (Arthur Deloraine) Fellowship. Founded 1928. Open to graduates of Harvard College. Available abroad for study of classical philology and archaeology. Stipend, $1100 a year.

Cummings (Francis Hathaway) Scholarships. (Arch.) Founded by Charles A. Cummings and Margaret K. Cummings, 1898, in memory of their son. Available for graduate study in landscape architecture. Stipend, $400 a year.

Derby (George and Martha) Scholarship. (Gr.) Founded by Miss Martha Derby, 1881. Available for graduate study in the arts and sciences. Stipend, $450 a year.

Doe (Orlando W.) Scholarship. (Med.) Founded by bequest of Orlando Witherspoon Doe, 1893. Stipend, $150 a year.

Eliot (Charles) Traveling Fellowship in Landscape Architecture. (Arch.) Open by competition to masters in landscape architecture of Harvard University, and to men who have already been recommended by the School of Landscape Architecture for this degree. Stipend, $1500 a year.

Emerson (George H.) Scholarships. (Gr.) Three. Founded by George H. Emerson, 1903. Open only to students who are not paid assistants in, and are regular graduates of, one of the departments of geology, mineralogy and chemistry, who are desirous of continuing their studies in any one of these departments. Stipend, $540 a year.

Eveleth (Joseph) Scholarships. (Arch., Eng.) Founded from the residuary bequest of Joseph Eveleth, 1896. Stipend, $300 a year.

Exchange of Scholarships with European Universities. (Gr.) By special arrangements with École Libre des Sciences Politiques, at Paris, and the University of Lyons, exemption from tuition charges may be granted annually at each of these institutions to one student or graduate of Harvard University, to be recommended by the President of Harvard University. The same privilege is granted to one of their students or graduates who desires to carry on advanced studies in Harvard University Graduate School of Arts and Sciences. Similar arrangements may be made with other European universities.

Farnham (Horace Putnam) Fellowship. (Med.) Two. Founded by Mrs. Eliza Cary Farnham, 1918, in memory of her husband. Stipend, $300 a year.

Folsom (Charles Follen) Fellowship. (Med.) Founded by more than sixty persons in memory of Dr. Charles F. Folsom. Open as a teaching fellowship in hygiene or in mental and nervous diseases, and for the present assigned to the Department of Hygiene. Stipend, $750 a year.

Gibbs (Virginia Barrett) Scholarship. (Gr.) One or more. Founded by Theodore K. Gibbs, 1892. Available for advanced study in zoology, preferably marine zoology. Stipend, $500 a year.

Goodwin (William Watson) Fellowship. (Gr.) Founded by William W. Goodwin, 1915. Available to a graduate student of classical literature or archaeology who shall be approved by the Classical Department of Harvard College. Stipend, one at $675, one at $500.

Greene (Charlotte) Scholarship. (Med.) Founded 1925. Open to a first year student whose previous record indicates special promise. Stipend, $225 a year.

Harris Fellowship. (Gr.) Founded by William Minot, Jr., as executor of the will of Henry Harris of Boston, 1868. Open to unmarried graduates for study in subjects other than law, theology or medicine. Stipend, $675 a year.

Harvard (John) Fellowships. (Gr.) Founded 1895. Awarded on grounds of high scholarship and promise. They may be either resident or non-resident students and are selected on nomination of several divisions or departments. No stipend.

Harvard (Lionel de Jersey) Studentship. (Gr.) Established 1924 by the Associated Harvard Clubs in memory of Lionel de Jersey Harvard, A. B., 1915, who was killed in the World War. The scholarship is available for graduates of Harvard College for study at Emmanuel College, Cambridge, England.

Haven (George) Scholarship. (Med.) Founded by Dr. George Haven, 1913. Apportioned among first-year students. Stipend, $1100 a year.

Hayden (Lewis and Harriet) Scholarships. (Med.) Founded by Mrs. Harriet Hayden. Open to colored students. If not awarded in the Medical School, this scholarship is open to colored students in any other department of the University. Stipend, $300 a year.

Hemenway Fellowship. (Gr.) Founded by Mrs. Mary Hemenway, 1891. Open to graduate students for study in American archaeology and ethnology at Harvard. Stipend, $740 a year.

Hilton Scholarship. (Med., Eng.) Two. Founded by bequest of William Hilton. Stipend, $350 a year.

Hodges (Priscilla Clark) Scholarship. (Gr.) Founded by bequest of Mrs. Priscilla Clark Hodges, 1907, with a principal of $4000. Available for research in applied biology. Stipend, $275 a year.

Hooper (Edward William) Fellowship. (Gr.) Founded by Henry Lee Higginson and others, 1905. Available at this University or abroad, for advanced research in the arts and sciences. Stipend, $1400 a year.

Jennings (Hennen) Scholarship. (Eng.) Founded by Hennen Jennings, 1898. Open to a student in mining or metallurgy. Stipend, $385 a year.

Johnson (William Otis) Scholarship. (Med.) Founded by Mrs. Johnson in memory of her husband. Stipend, $200 a year.

Jones (Claudius M.) Scholarship. (Med.) Founded by Claudius Jones, 1893. Stipend, $350 a year.

Kirkland (John Thornton) Fellowship. (Gr.) Founded by George Bancroft, 1873. Incumbent must have resided three years at the University as a member of the College or any of the Schools. Available for study in the arts and sciences at Harvard. Stipend, $725 a year.

Lincoln Scholarship. Founded by Miss Levina Hoar, 1876. Open to undergraduates or graduates, preference being given to students from Lincoln, Mass. Stipend, $550 a year.

Linder (Alfred Hosmer) Scholarship. (Med.) Founded by Mrs. George Linder, 1895. Awarded to a student of sound principles and marked ability. Stipend, $275 a year.

Mears (J. Ewing) Scholarship. (Med.) Founded by J. E. Mears, 1920. Open to a student throughout his full four years course, subject to his scholastic standing and good conduct. Stipend, $200 a year.

Moseley (William O., Jr.) Traveling Fellowships. (Med.) Two or three. Founded by Mrs. Wm. O. Moseley, 1912. Open to students who have attended the School for three or four years, to enable them to continue the study of medicine in Europe. Either two or three fellowships will be awarded from the income, which is approximately $5200. Applications for these fellowships should be made to the Dean on or before March 1st.

Mowlson (Lady) Scholarship. Founded by Lady Ann Mowlson of London, 1643. Preference will be given to any of Lady Mowlson's kinsmen. Available in Harvard for graduate or undergraduate study. Stipend, $500 a year.

Norton (Charles Eliot) Fellowship. (Gr.) Founded by James Loeb, 1901, in memory of Charles Eliot Norton. Open to graduates or undergraduates of Harvard. Awarded on the basis of a thesis written on an approved subject, and on such other evidence of scholarship as may be accessible. Holder may study at American School of Classical Studies at Athens, and devote himself to study of some special subject approved by the committee in the field of Greek history, literature, art, archaeology, epigraphy or topography. Stipend, $1250 a year. Applications should be filed by December 1st with Chairman of the Department of Classics.

Oliver (Joseph Pearson) Scholarship. (Med.) Founded by patients of Joseph Pearson Oliver, 1904. Stipend, $475 a year.

Parker Fellowships. (Gr.) Four. Founded by John Parker, Jr., 1873. Open to students in Harvard College or in any other department of the University for study in the sciences. Available as a traveling fellowship. Stipend, $1500 a year.

Parkman (Francis) Fellowship. (Gr.) Founded by Miss Eliza W. S. Parkman, 1905. Available for advanced study in the arts and sciences. Stipend, $650 a year.

Peirce (James Mills) Scholarship. (Gr.) Founded by several donors, 1927, in memory of Professor Peirce. Open to students in the Graduate School recommended by the Division of Mathematics. Stipend, $550 a year.

Perkins (Charles Elliott) Scholarships. Two. Founded by Mrs. Charles Elliott Perkins, 1909. Preference given to graduates of an Iowa college or university. Stipend, $500 a year.

Porter (Charles B.) Scholarship. (Med.) Founded by W. L. Chase, 1897. Stipend, $300 a year.

Princeton Fellowship. Founded by an alumnus of Princeton University, 1910. Preference given to a graduate of Princeton University. Stipend, $675 a year.

Public Health Fellowships. (Pub. H.) The School offers a limited number of fellowships of varying amounts but not exceeding $1200 each. They are open to students of high scholarship and exceptional ability. Applicants whose experience and training have fitted them to pursue an original piece of research work along lines of public health, will be given preference. No fellowship will be granted to a student spending less than one academic year at the School. Applications should be filed with the Secretary of the School of Public Health.

Richardson (Jeffrey) Fellowship. (Gr.) Established 1933 by Dr. William L. Richardson for a deserving student upon his graduation who desires to continue his studies either in this country or abroad. The Fellowship may be awarded to the same student for a second year if he shows himself worthy. Stipend, $1400 a year.

Robinson (Nelson, Jr.) Traveling Fellowship in Architecture. (Arch.) Founded from the income of the Nelson Robinson, Jr., Memorial Fund, 1902. Stipend, $2200 a year.

Rumrill (James A.) Scholarship. Founded by Mrs. J. A. Rumrill, 1909. Open to a properly qualified graduate of a college or university in Virginia, North Carolina, South Carolina, Florida, Georgia, Tennessee or Kentucky, who desires to study in one of the graduate departments of Harvard University. Stipend, $425 a year.

Russell (Edward) Scholarship. (Gr.) Founded by Edward Russell, 1877. Available for advanced study in the arts and sciences. Stipend. $475 a year.

Saltonstall (Leverett) Scholarship. (Gr.) Founded by Leverett and Henry Saltonstall, 1895. Preference given to descendants and relatives of Leverett Saltonstall. Stipend, $800 a year.

Sanger (Ralph) Scholarships. (Gr.) Five. Founded by Miss Irene C. Sanger. Stipend, $400 a year.

Savage (James) Scholarships. (Gr.) Founded by James Savage, 1873. Stipend, $500 a year.

Sawin (George William) Fellowship. (Gr.) Founded by several donors, 1926, in memory of George W. Sawin. Open to student of mathematics. Stipend, $625 a year.

Scholarships for Special Students in Architecture. (Arch.) Three. Awarded as the result of a competition in architectural design to candidates who have fulfilled all the requirements demanded of special students. Stipend, $400 a year.

Searle (Flavius) Scholarship. (Med., Eng.) Founded by Miss Mary L. Searle in memory of her father, 1921. Income of $325 may be divided in Medical School. In Engineering School, the stipend is $350 a year.

Sears (Philip H.) Scholarship. (Gr.) Founded by Mrs. Philip H. Sears, 1914. Assigned on recommendation of the Department of Philosophy and Psychology for study in these subjects. May be held at Harvard or abroad, or as a traveling fellowship. Stipend, $950 a year.

Sheldon (Frederick) Fund For Traveling Fellowships. Founded by Mrs. Amey Richmond Sheldon, 1909. Appointee must at the time of his appointment be a member of the University. The fellowship is not available for study in Harvard, but may be held in any other American university or abroad. Recommendations are made to the Committee on the Sheldon and other General Fellowships from various departments and schools, and the fellowship is assigned as the Committee shall deem most expedient for purposes of investigation or study. No fixed stipend.

Storrow (Charles Storer) Memorial Fund. (Eng.) Founded 1927 in memory of Charles Storer Storrow, who drew up the plans for a scientific school which was established in 1847 as the Lawrence Scientific School, and has since become the Harvard Engineering School. Available for scholarships, loans or other aid. Total income, $1150 a year.

Stoughton Scholarships. (Gr.) Established for students registered in any department of the University. Preference: first, students from Dorchester; second, students from Milton, Mass. Applications from students registered in the Graduate Departments of the University should be made to the Chairman of the Committee on General Scholarships of the Sheldon Fund. Several scholarships are awarded annually from a total income of $4500.

Strong (Charles Pratt) Scholarship. (Med.) Founded by friends and patients of Charles Pratt Strong, 1894. Stipend, $250 a year.

Sweetser (Isaac) Scholarships. (Med.) Founded by Mrs. Anne M. Sweetser, 1892. Stipend, $350 a year.

Taylor (John Thomson) Scholarship. (Med.) Founded by Mrs. Frederic D. Philips in memory of her brother. Stipend, $275 a year.

Thayer Fellowships. (Gr.) Five. Founded by John Eliot Thayer, 1857. Available for advanced study in the arts and sciences. Stipend, $625 a year.

Thayer Scholarships. (Gr.) Founded by John Eliot Thayer, 1857. Available for advanced study in the arts and sciences. Stipend, $450 a year.

Thomas (Gorham) Scholarship. (Gr.) Founded by Alexander Thomas, 1865. Available for advanced study in the arts and sciences. Stipend, $400 a year.

Townsend Scholarships. (Gr.) Five. Founded by Miss Mary P. Townsend, 1861. Available for advanced study in the arts and sciences. Stipend, $500 a year.

Tyndall (John) Fellowship. (Gr.) Founded by Professor John Tyndall, 1885. Open to "one or more American pupils who may have shown decided talents in physics, and preferably such as shall express the determination to devote their lives to the advancement of theoretic science and original investigation in that department of learning." Stipend, $750 a year.

University Fellowships. (Gr.) Seventeen. Founded by the University, 1928. Stipend, $550 a year.

University Scholarships. Thirty-six. Founded by the University, 1891. Of these, one-half, approximately, are to be assigned annually by preference to seniors of high standing in Harvard and in other colleges for study in the Graduate School of Arts and Sciences during the next academic year, regard being had in the assignment to the geographical distribution of the beneficiaries. Stipend, $400 a year.

University Scholarships (For architecture and landscape architecture). (Arch.) Six. Stipend equal to tuition in any case.

Walcott (Henry Pickering) Scholarship. (Med.) Founded by Frederick Cheever Shattuck, 1910. Available for a fellow in clinical medicine appointed on nomination by the Jackson Professor of Clinical Medicine. The recipient shall not engage in private practice during the period of his incumbency, but must devote his time to teaching and clinical research. Stipend, $1700 a year.

Walker Scholarships. (Med.) Founded by bequest of Miss Leslie Walton Walker. There are four of these scholarships: Charles Walker Scholarship, Helen L. Walker Scholarship, Anna G. Walker Scholarship, Leslie W. Walker Scholarship. Stipend in each case, $300 a year.

Watson (Abraham A.) Scholarship. (Med.) Founded by Miss Catherine E. Walker. For the benefit of students of the Medical School. Stipend, $425 a year.

Webster **(Major Harrison Briggs) U. S. Army Scholarship.** (Med.) Founded by Mrs. L. Florence Webster in memory of her son. Preference given to sons of members of the Class of 1905, but if there is no such applicant, the scholarship may be awarded to a student of sound principles and marked ability. Stipend, $220 a year.

Weld (Christopher M.) Scholarship. (Gr.) Founded by Mrs. Mary Ann P. Weld, 1899. Available for advanced study in the arts and sciences. Stipend, $675 a year.

Whiting Fellowships. (Gr.) Four. Founded by Harold Whiting, 1895. Available for advanced study in physics. Stipend, $450 a year.

Wigglesworth (Edward) Scholarship. (Med.) Founded by the family of Edward Wigglesworth, 1897. Stipend, $275 a year.

Winthrop (Robert C.) Scholarship. (Gr.) Founded by Robert C. Winthrop, 1895. To be assigned to the Peabody Museum of Archaeology and Ethnology for study in these subjects. Stipend, $500 a year. Applications should be filed with the Director, Peabody Museum.

Woodworth (Jay Backus) Fellowship. (Gr.) Founded 1931 by some 85 alumni of the University to commemorate the lifelong services of Professor Woodworth. Preference is given to a candidate who has shown decided capacity in the pursuit of geology and good promise of advancing the science. Applications with supporting credentials should be addressed to the Chairman of the Division of Geology not later than the first of March. Original amount, $25,000. Income available as stipend.

Workman (William Hunter) Fellowship. (Med.) Four. Founded by William Hunter Workman, 1923, for the assistance of one or more needy and deserving graduates in Harvard University Medical School, to pursue postgraduate studies in medicine in this country or abroad. In exceptional cases, fourth-year students will be eligible. Stipend, $1200 a year.

Wyman (Jeffries) Scholarships. (Gr.) Founded by Mrs. William Morris Davis. The income to be paid each year to one, two or more students in a graduate department of the University who give promise of success in some branch of biological research. The selection is to be made by the Hersey Professor of Anatomy, the Stillman Professor of Comparative Anatomy and the Curator of the Zoological Museum. Stipend, $575 a year.

HAWAII, UNIVERSITY OF, Honolulu, Hawaii.

The University of Hawaii offers two and in some years more annual fellowships for research in entomology, soil chemistry and other subjects pertaining to tropical agriculture; they provide stipends varying from $1000 to $1500 per year. Individual cases are considered according to their merits and to the current availability of funds.

HOSPITAL FOR JOINT DISEASES, 1919 Madison Ave., New York, N. Y.

Brown (Mr. and Mrs. Frederick) Orthopedic Research Fellowships. Two. Established 1927, by Mr. and Mrs. Frederick Brown, for study at the Hospital for Joint Diseases. Open to men and women with research and investigational experience and the necessary university education with science or doctor of medicine degree, and interest in any field of pure science or the art and science of medicine leading to further study of any material relating to orthopedic surgery or the skeletal system. Stipend, $2400 a year. Applications should be filed on special form furnished by Dr. J. J. Golub, Director.

Frauenthal (Henry W.) Travel Scholarship. Established 1927 by the late Dr. Henry W. Frauenthal. Open to men and women, graduates and staff members of the Hospital for Joint Diseases for study for six months abroad and six months in the United States. Applicants must have a special interest in the sciences allied to orthopedic surgery or the skeletal system. Stipend, $2400 a year. Applications should be filed during January, February or March on special form furnished by Dr. J. J. Golub, Director.

HUNTER COLLEGE OF THE CITY OF NEW YORK, Park Ave. and 68th St., New York, N. Y.

Gillet (The Joseph A.) Scholarship Fund. Established 1907 by the Department of Mathematics for research. No restrictions as to place of study. Open to women who are members of the graduating class, Department of Mathematics. Stipend, $45 a month.

Seringhaus (Else) Scholarship Fund. Founded by the Science Club of Hunter College, 1911. Open to women who are students in this College, and are designated by the President on recommendation of the Science Club. Available at the Woods Hole Marine Biological Laboratory for study during the summer months. Stipend, $50. At times the fund is extended by awards from the Natural Science Club, permitting two or more students to go together.

IDAHO, UNIVERSITY OF, Moscow, Idaho.

Agricultural Engineering Teaching Fellowship. Founded 1930. Open to men with a B. S. degree in engineering or agriculture, majoring in agricultural engineering, who are qualified for instruction in agricultural engineering laboratory assistance. Stipend, $437.50 to $450 a year. Applications should be filed not later than August with the Department of Agricultural Engineering.

Crites (Willis E.) Fellowship. Founded 1933 by Willis E. Crites for research in agricultural engineering power and machinery application. Open to men with a B. S. degree in engineering or agriculture majoring in agricultural engineering. Available only in this University. Stipend, $300 a year. Applications should be filed not later than August with Department of Agricultural Engineering.

Fellowship in Forest Pathology. Established by the School of Forestry for research in forest pathology. Open to men who are graduates with degree of B. S. in forestry. Stipend, $525 a year for a ten months' period. Applications should be filed before July with School of Forestry.

Moscow Pea Growers Association. Established 1932. Open to men with B. S. degree for the study of agronomy in this University. The major must have been in agronomy, minor in botany. Stipend, $300 a year. Applications should be filed by February 1st with Head, Department of Agronomy.

Teaching Fellowship in Botany. Founded 1910. Open to men and women with a B. S. or a B. A. degree with major in botany, two years of French or German and two years of chemistry, under twenty-six years of age. Available in this University for the study of botany. Stipend, $525 a year. Applications should be filed by March 1st on special form with Head, Department of Botany.

Teaching Fellowship in Geology. Founded 1923. Open to men and women with bachelor's degree, who are recent graduates. Two year teaching fellowship in geology leading to a master's degree. Stipend, $500 for ten months. Applications should be filed by April 1st on special form furnished by School of Mines, University of Idaho.

Teaching Fellowship in Physics. Founded 1927. Open to men and women, men preferred, with bachelor's degree with a major in physics. Stipend, $437.50 for ten months. Applications should be filed by April 1st with Head, Department of Physics.

Zoology Department Teaching Fellowships. Two to three. Open to men and women with a bachelor's degree from standard institution, with preference for those who have recently graduated. Available for research in zoology in this University. Stipend, $427.50 for ten months. Applications should be filed not later than March 15th in special form furnished by Head, Department of Zoology.

ILLINOIS, UNIVERSITY OF, Urbana, Ill.

Carr Fellowship in Chemistry. Founded by Robert F. Carr, 1919. Open to men and women not over thirty years of age. Stipend, $750 per year. Applications should be filed by March 1st with the Graduate School. Special application form furnished.

Graduate Scholarships and Fellowships in Public Utilities. Established in 1924 by seven public utilities companies. Stipend for fellowships, $500 to $700 per year; for scholarships, $300. Applications should be filed by March 1st with the Graduate School. Special application form is furnished.

Kinley (Kate Neal) Memorial Fellowship. Established in 1931 by Dr. David Kinley. Open to men and women of not over 24 years of age, who are graduates of College of Fine and Applied Arts at the University of Illinois or of other schools of similar standing. Restricted to advanced study in fine arts. Stipend, $1000. Applications should be filed by April 1st with Chairman, Kate Neal Kinley Memorial Fellowship Committee, College of Fine and Applied Arts, Urbana, Illinois.

Plym Fellowship in Architecture. Founded 1924, by Francis J. Plym, for the study of architecture. Open to men and women under thirty years of age, graduates of the Department of Architecture of the University of Illinois. The award is based on competition. Available for study abroad. Stipend, $1200 a year. Applications should be filed by January 10th on special form furnished by the Department of Architecture.

Plym Foreign Scholarship in Architectural Engineering. Founded 1924, by Francis J. Plym, for the study of architecture and engineering abroad. Open to men and women, under thirty years of age, who are graduates of the Department of Architecture of the University of Illinois. Award based on competition in architectural design, construction, history of architecture, mechanics of materials and details. Applications should be filed by April 15th on special form furnished by the Department of Architecture.

University Fellowships. Open to men and women with one or two years of graduate work, who are not over thirty years of age. Stipend, $400 to $500 a year. Applications should be filed by March 1st with the Graduate School. Special application form furnished.

University Scholarships. Open to men and women who are not over thirty years of age. Without stipend. Applications should be filed by March 1st with the Graduate School. Special application form furnished.

See also Clay Products Association.

INDIANA UNIVERSITY, Bloomington, Ind.

Applications should be filed before March 1st with the Dean of the Graduate School. Special application form furnished. All fellows are exempted from the payment of contingent fees.

Lawrence Fellowship in Astronomy. Founded by Percival Lowell. Applicant shall be appointed by the Department of Astronomy, the Lowell Observatory reserving the right of finally passing upon the suitability of the candidate so presented. Fellow shall be given time and opportunity for an original thesis on some astronomical subject looking to the taking of a master's degree, the nature of which shall be decided by the Director and the Fellow, and he shall be expected to give general assistance in the work of the Observatory. Stipend, $600 and traveling expenses to and from the Observatory at Flagstaff, Ariz., and a furnished room at the Observatory.

University Fellowships. Six. Open to graduate students who have had at least a year of graduate work. Stipend, $600 a year. Temporarily withdrawn for 1933-34 and 1934-35.

INSTITUTE FOR JUVENILE RESEARCH, Paul L. Schroeder, M. D., Director, 907 South Lincoln St., Chicago, Ill.

Seven fellowships are awarded annually. Open to men and women for research in psychiatry, psychology and social work. Stipend, $45 to $90 a month. Fellowships are offered by an arrangement with the State Department of Public Welfare.

INSTITUTE OF INTERNATIONAL EDUCATION, 2 West 45th St., New York, N. Y.

Exchange Fellowships for study abroad are offered under the auspices of the Institute of International Education. Through the ministries of education of various European countries, the universities and higher educational institutions, in return for similar opportunities in the United States, offer grants covering board, lodging and tuition to American students to pursue general graduate work abroad. These fellowships vary in number from year to year and are administered by the various Student Exchanges of the Institute of International Education as follows: Austro-American, American Czechoslovak, Franco-American, American German, American Hungarian, American Italian, American Spanish and Swiss American Student Exchanges. They are open to unmarried American men and women who will have received at least the A. B. degree at time of entering upon the fellowship; who have a practical reading, writing and speaking knowledge of the language of the country in which they wish to study; and who are under thirty years of age. Special blanks are required for each Exchange and must be filed before January 15th (except in the case of France for which the closing date is February 1st). For further information address the Student Bureau, Institute of International Education.

INSTITUTE OF MEDICINE OF CHICAGO, Chicago, Ill.

Koessler (Jessie Horton) Fellowship and Lectureship Fund. Established 1930 by Dr. Karl Konrad Koessler. For three successive years the fund is to be used for a fellowship in research in biochemistry, physiology, bacteriology or pathology, and in every fourth year to provide an honorarium for a lecture to be delivered before the Institute of Medicine of Chicago on the results of research work. Original amount, $10,000. Annually available, approximately $500. Applications for fellowship are received up to December 15th by the Secretary of the Institute of Medicine, 122 South Michigan Boulevard, Chicago.

INSTITUTE OF PAPER CHEMISTRY, Appleton, Wis.

Fellowships. Nine during 1933-34. Founded by Mrs. Ernst Mahler, J. S. Sensenbrenner, Sam Sutphin, Edgar Brothers, E. I. du Pont de Nemours & Company, Neenah Paper Company and Paper Makers Chemical Corporation. Open to men who are graduates of an accepted college or university presenting necessary qualifications for registration. Available in the Institute only. Stipend, $200 to $650 a year. Applications should be filed, on special form furnished, prior to July 1st with the Dean of Students of the Institute.

IOWA STATE COLLEGE OF AGRICULTURE AND MECHANIC ARTS, Ames, Iowa.

Clinton Company Scholarship. Established 1933, for the study of utilization of the byproducts of the Clinton Company. Open to men or women with a B. S. degree in biological or chemical science. Stipend, $450 a year. Available only at Iowa State College. Applications should be filed by March 1st on special form furnished by the Dean of the Graduate College.

Dairy and Ice Cream Machinery and Supplies Association, Inc., Scholarship. Established 1928, for ice cream research at Iowa State College. Awarded biannually. Stipend, $600 a year. Open to men with a

B. S. degree in dairy industry. Applications should be filed by March 1st on special form furnished by the Dean of the Graduate College.

Iowa Mutual Tornado Insurance Scholarship. Established 1930, for research in agricultural engineering. Open to men with a B. S. degree in agricultural engineering. Stipend, $750 a year. Applications should be filed by March 1st on special form furnished by the Dean of the Graduate College.

Memorial Union Fellowship. Founded 1928. Open to women with the degree of bachelor of science and background of dietetics, foods and institutional administration. Available in this University for the study of institutional administration. Stipend, $450 a year. Applications should be filed by April 1st with Institutional Administration Department. Special application form furnished.

Parke, Davis and Company Fellowship. Number varies. Founded by Parke, Davis and Company, 1928. Open to men, preferably, with the degree of bachelor of science and training in organic chemistry. Available in this University for research upon some designated problem in chemistry. Stipend, variable. Appointments are made by the Chemistry Department.

Research Fellowships. Sixty-eight in 1933-34. Open to men and women with the degree of bachelor of science and training in the field offering the fellowship. Available in the Department offering the fellowship for research on subject closely related to one of the approved Experiment Station projects. Stipend, $450 a year. Applications should be filed by April 1st with the Dean of the Graduate College. Special application form furnished.

Research Scholarships. Eighteen in 1933-34. Open to men and women with the degree of bachelor of science and training in the field offering the scholarship. Available in the Department offering the scholarship, for research on some subject closely related to one of the approved Experiment Station projects. Stipend, $225 a year. Applications should be filed by April 1st with the Dean of the Graduate College. Special application form furnished.

Teaching Fellowships. Twenty-two in 1933-34. Open to men and women with degree of bachelor of science and training in the field offering the fellowship. Available in the Department offering the fellowship for research. Stipend, $450 a year; a minimum requirement of five hours per week in class room, or ten to twelve hours in the laboratory, or performing equivalent allotted duties for the Department granting the fellowship. Applications should be filed by April 1st with the Dean of the Graduate College. Special application form furnished.

Teaching Scholarships. Two in 1933-34. Open to men and women with the degree of bachelor of science and training in the field in which the scholarship is offered. Available in the Department offering the scholarship for research. Stipend, $225 a year; minimum requirement of three hours per week in the class room or six hours in the laboratory, or performing equivalent allotted duties for the Department granting the scholarship. Applications should be filed by April 1st with the Dean of the Graduate School. Special application form furnished.

IOWA, STATE UNIVERSITY OF, Iowa City, Iowa.

Corn Industries Research Foundation Fellowship, for research in certain clinical properties of dextrose. Total amount of grant, $500.

Eastman (George S.) Fellowships. Five. Established 1927 by George S. Eastman for study of the psychology of music. Open to men and women with a bachelor's degree and with outstanding ability in psychology and music. Available for study only in this University. Applications should be filed by March 1st with Dean of Graduate College.

Graduate Assistantships. About 45 on one-half time basis and 30 on one-fourth time basis. Open to men and women with a master's degree. Stipend, $450 and $225 a year, respectively, with reduced tuition; 20 to 24 hours a week required in service. Application should be filed by March 1st with head of department concerned. Special application form furnished.

National Live Stock and Meat Board Fellowship, for research in liver protein. Total amount of grant, $750. Stipend, $35 a month.

Research Assistants. Thirty-nine on one-half time basis and 27 on one-fourth time basis. Open to men and women with a master's degree, who are qualified for research in specific field assigned. Stipend, $450 and $225, respectively, with reduced tuition; 24 hours per week and 12 hours per week, respectively, required in service. Applications should be filed by March 1st, with head of department concerned. Special application form furnished.

Research Associates. Fifteen. Open to men and women with a Ph. D. degree, who are below 35 years of age. Stipend, $450 per year and up. Application should be filed by March 1st with Dean of Graduate College.

Tuition and Room Scholarships. Sixty-four. Open to men and women with an A. B. degree. Stipend, tuition valued at $96 per year and room valued at $80 per year. Twelve hours per week required in service. Application should be filed by March 1st, with Dean of Graduate College. Special application form furnished.

Tuition Scholarships. Thirty-seven. Open to men and women with an A. B. degree. Stipend, tuition valued at $96 per year. Six hours per week required in service. Application should be filed by March 1st, with Dean of Graduate College. Special application form furnished.

ITALY AMERICA SOCIETY, The Waldorf-Astoria Hotel, New York, N. Y.

Volta (Alessandro) Fellowship. Founded 1927. Open to men with Italian engineering degree and a knowledge of English. Available in any American university for general scientific study. Stipend, $1800 a year. Applications should be filed with the Associazione Elettrotecnico Italiana, Milan, Italy.

JEFFERSON MEDICAL COLLEGE, Philadelphia, Pa.

Gratz (Simon) Research Fellowship. Awarded during each period of three years. Established 1926, by Simon Gratz, for medical research. Open to graduates of the Jefferson Medical College, and awarded to that graduate who shall be named by the Faculty of the College as most worthy to receive it for what he shall have done within five years next preceding the award for the advancement of the medical or surgical treatment of diseases or in research work that has been productive of results having a real practical value. Available only in this College. Stipend, $1000 a year.

Keen (Corinna Borden) Research Fellowship. Appointment made whenever the accumulated income amounts to $1000. Founded 1905, by Dr. W. W. Keen, for medical research. Open to graduates of the Jefferson Medical College of not less than one nor more than ten years' standing. A condition of the award is that the Fellow shall spend at least one year in Europe, America or elsewhere in medical research, and shall publish at least one paper embodying the results of his work. Stipend, $1000 a year.

Mears (J. Ewing) Research Fellowship. Founded 1930, by J. Ewing Mears, for medical research in Jefferson Medical College. Open to men who have the M. D. degree. The course of study must be on conditions that may better the physical and moral qualities of future generations. Stipend, $3500 a year.

Mears (J. Ewing) Scholarship in Medicine. Awarded whenever the accumulated income from the fund is sufficient. Founded 1919 by J. Ewing Mears.

Shain (Francis W.) Scholarships. Two. One awarded every two years. Established 1897, by Dr. Francis W. Shain, for medical education. Open to white, male graduates of the Boys' High Schools of Philadelphia who have completed acceptable pre-medical college work. Available only in this College. Stipend, tuition fee amounting to $400 a year is remitted.

Strittmatter Teaching Research Fellowship. Awarded when the accumulated income is sufficient. Founded 1923, by Dr. I. P. Strittmatter, as a trust fund to maintain a Research Laboratory composed of interrelated laboratories of physiological chemistry, pharmacology and bacteriology. The suggestion of the grantor is that special attention be given to the study of cancer, tuberculosis and the rapidly increasing heart diseases, and such other causes of suffering and death as may from time to time appeal to the medical profession. Open to men with a M. D. degree for medical research in this College.

Trustees' Scholarships. One awarded every two years. Open to graduates of the Boys' High Schools of Philadelphia who shall have completed the acceptable pre-medical college work. Available only in this College for medical education. Stipend, tuition fee, which amounts to $400 a year, is remitted.

JOHNS HOPKINS UNIVERSITY, Baltimore, Md.

Anonymous Fellowship for the Study of Chemistry. Given by an anonymous donor to a graduate student in chemistry who has, as an undergraduate, a high record in mathematics and physics as well as chemistry, and who has shown the greatest ability in overcoming obstacles in the way of obtaining his education. Applications should be filed by February 15th with Dr. Neil E. Gordon, Johns Hopkins University.

Archbold (John D.) Fellowship. Three or four. Established 1929, by Mrs. John D. Archbold, for research in medicine. Open to men and women who are approved by Professor of Medicine. Available only in Johns Hopkins University School of Medicine. Stipend, $1500 to $1800 a year. Applications may be filed at any time with the Professor of Medicine.

Bruce (Adam T.) Fellowship. Founded by the mother of Adam T. Bruce, 1887. Open to men and women who have shown fitness to conduct an important investigation which will promote biological science. Available for research in the biological sciences, particularly zoology. Stipend, income of $30,000 and exemption from tuition and laboratory fees. Fellow may be reappointed, but not oftener than twice. Applications should be filed by March 1st with the President of the University.

Copley (Edith Strohn) Fellowship. Established 1929, by Ira Copley, for study of ophthalmology. Open to men and women approved by the Professor of Ophthalmology, for study in the Johns Hopkins University School of Medicine. Stipend, $1200 to $1500 a year. Applications may be filed at any time with the Professor of Ophthalmology.

Fellowships for the Study of Chemistry. Eighteen. The Chemistry Department of this University has a program for a study in the selection and education of prospective leaders in the field of chemistry. In the study emphasis is laid upon the selection of men to be trained and the training of men selected. In order to limit the project, and at the same time, place it upon a truly national basis, the plan makes ultimate provision for one student from each of the forty-eight states. Selection is to be made from the sophomore, junior or senior classes of the colleges and universities of the respective states and is to be accomplished through State committees. As an assurance that men of unusual promise shall not be debarred by lack of funds, a four-year fellowship of $1000 annually will be offered in each state. Requests for application blanks and all correspondence connected therewith should be addressed to Dr. Neil E. Gordon, Chemistry Department, the Johns Hopkins University. The completed application blank must reach the Department on or before March 1st. The recipient of the fellowship will be notified of his appointment on or before April 1st. The Fellowships so far have been founded by the following companies and bear their names as indicated:

AMERICAN CAN COMPANY $1000 FELLOWSHIPS. Three. Provided by this Company for the States of California, Oregon and Utah.

CENTRAL SCIENTIFIC COMPANY $1000 FELLOWSHIP. Provided by this Company for the State of Illinois. (Not available 1934-35.)

CHEMICAL FOUNDATION, INC., $1000 FELLOWSHIPS. Two. Provided by the Foundation for the States of Arizona, Nevada and New Mexico (one), and for Idaho, South Dakota and Wyoming (one).

COCA-COLA COMPANY $1000 FELLOWSHIP. Provided by this Company for the State of Georgia.

CUDAHY PACKING COMPANY $1000 FELLOWSHIP. Provided by this Company for the State of Nebraska.

DUNNING (H. A. B.) $1000 FELLOWSHIP. Provided by Dr. H. A. B. Dunning of Hynson, Westcott and Dunning, Baltimore, for the State of Maryland.

FLEISCHMANN COMPANY $1000 FELLOWSHIP. Provided by this Company for the State of Washington.

GARVAN (FRANCIS P.) $1000 FELLOWSHIPS. Three. Provided by Mr. Garvan for the States of New York, Connecticut and one at-large.

GENERAL MOTORS CORPORATION $1000 FELLOWSHIP. Provided by this Company for the State of Michigan. (Not available 1934-35.)

HANCOCK (JOHN M.) $1000 FELLOWSHIP. Provided by this Company for the State of North Dakota.

HORMEL FOUNDATION $1000 FELLOWSHIP. Provided by the Foundation for the State of Minnesota.

KEWAUNEE MANUFACTURING COMPANY $1000 FELLOWSHIP. Provided by this Company for the State of Wisconsin. (Not available 1934-35.)

LILLY (ELI) AND COMPANY $1000 FELLOWSHIP. Provided by this Company for the State of Indiana.

PATRICK (W. A.) $1000 FELLOWSHIP. Provided by Dr. W. A. Patrick for England.

PFEIFFER (G. A.) $1000 FELLOWSHIP. Provided by Mr. Pfeiffer for the State of Iowa.

REYNOLDS (R. J.) TOBACCO COMPANY $1000 FELLOWSHIP. Provided by this Company for the State of North Carolina.

SPEED (WILLIAM S.) $1000 FELLOWSHIP. Provided by Mr. Speed for the State of Kentucky.

WARNER (WILLIAM R.) AND COMPANY, INC. $1000 FELLOWSHIP. Provided by this Company for the State of Missouri.

Gas Engineering Scholarships. There are a number of gas companies throughout the United States which offer special scholarships in the department of Engineering. They may be held by graduate or undergraduate students. Such scholarships grant free tuition. Inquiries may be addressed to the Assistant Dean of the School of Engineering.

Graduate Scholarships in Engineering. Four. Open to men who have shown an interest in research and are in need of financial assistance to pursue advanced work. Available in this University for research in engineering. Stipend, $336 a year (tuition and laboratory fees). Applications should be filed by September 1st with Dean Whitehead, Johns Hopkins University.

Grafflin (William H.) Scholarship. Founded 1918, by W. H. Grafflin. Open to an advanced student in chemistry, man or woman, who has the doctor's degree or who is approaching the completion of the work for this degree. Available in this University for research in industrial chemistry. Stipend, income from the fund, not to exceed $1000 a year. If the holder is a candidate for a degree, he is not exempted from tuition and other fees. Appointment is made for two years. Applications should be filed by March 1st with the President.

Halsted (Wm. S.) Fellowships in Surgery. Two. Founded 1922, by William Steward Halsted. Open to men and women approved by Professor of Surgery. Stipend, $1000 each a year. Available in the Johns Hopkins University School of Medicine. Applications may be filed at any time with Professor of Surgery, Johns Hopkins Hospital, Baltimore, Md.

Harcum (Cornelia) Scholarship. Established by Cornelia G. Harcum for study in classical archaeology. Open to women; the A. B. degree is usually required. Available only in this University. Stipend, income of the fund, not to exceed $300. No exemption from tuition or other fees. Applications should be filed by March 1st on special form furnished by Scholarship Committee.

Harkness Fellowship. Founded 1929, by Edward S. Harkness, for study of ophthalmology. Open to men and women approved by the Professor of Ophthalmology. Available in the Johns Hopkins University School of Medicine. Stipend, $1200 to $1500 a year. No date specified for applications, which should be sent to the Professor of Ophthalmology.

Hunterian Fellowship in Surgery. Founded 1926, by an anonymous donor. Open to men and women approved by Professor of Surgery. Available in this University only. Stipend, $1000 a year. Applications may be sent at any time to the Professor of Surgery, Johns Hopkins Hospital, Baltimore, Md.

Johnston Scholarships (The Henry E. Johnston, the James Buchanan Johnston and the Henry E. Johnston, Jr.). Three. Founded 1904, by Mrs. Harriet Lane Johnston. Open to men and women who have the doctor's degree or who are advanced graduate students and can give evidence of their power to conduct independent research. Available in this University only, unless permission is granted by the Academic Council to pursue study elsewhere. Appointments are for one year, but if work is satisfactory, holders are generally reappointed. Stipend, one third of the income of the fund, not to exceed $1500 a year; the incumbent may be required to do some teaching in addition to his research, but he may not engage in teaching elsewhere. Applications should be filed by March 1st with the President.

Jones (Harry Clary) Fellowship. Founded 1928, by Mrs. Harriet Brooks Jones, for study in physical chemistry. Open to men and women with doctor's degree or approximately the same preparation. Available only in this University. Stipend, income of fund, about $1000 a year. No exemption from tuition or other fees. Applications should be filed by March 1st with the Department of Chemistry.

Lewisohn (Adolph) Fellowship. Founded 1929, by Adolph Lewisohn for the study of ophthalmology. Open to men and women, approved by Professor of Ophthalmology. Available in Johns Hopkins University School of Medicine. Stipend, $1200 to $1500 a year. No date specified for filing applications, which would be sent to Professor of Ophthalmology, Johns Hopkins Hospital, Baltimore, Md.

Loeb (Jacques) Fellowships in Medicine. Variable number, usually two. Founded 1930, by anonymous donor, for study of medicine. Open to men and women, approved by Professor of Medicine, for study in the School of Medicine at this University. Stipend, $1200 to $1800 a year. No specified date for filing applications, which should be sent to the Professor of Medicine, Johns Hopkins Hospital. The money for these fellowships is given annually, hence it is not known how long they will be available.

Mellon Fellowship. Founded by A. W. and R. B. Mellon, 1929, for study of ophthalmology. Open to men and women, approved by Professor of Ophthalmology. Available in Johns Hopkins University School of Medicine. Stipend, $1200 to $1500 a year. No date specified for filing applications, which should be sent to Professor of Ophthalmology, Johns Hopkins Hospital, Baltimore, Md.

Quincy (Walter Cottrell) Fund Graduate Scholarships. Four. Founded 1914, by Mrs. Martha R. Quincy. Open to men and women who are graduate students in the Department of Physics, for research in that subject. Stipend, income of $20,000 divided among the four scholars. No exemption from tuition or other fees. Applications should be filed by March 1st with the President of the University.

Scholarships for Foreign Students. Twenty-five. Open to men and women who are citizens of a foreign country and who, at the time of application, are resident abroad. Stipend, tuition. Applications should be filed by March 15th with the President of the University.

Scholarships in School of Hygiene and Public Health. Twelve. Open to men and women for graduate study in hygiene and public health. Granted for one year at a time, but may be renewed for a second year. Stipend, tuition. Applications should be filed April 1st or December 1st with Director, School of Hygiene and Public Health.

Slack (Ella E.) Scholarship. Founded 1923, by Mrs. Ella E. Slack. Open to men and women who are graduate students in the Faculty of Philosophy, preference being given to those departments in which there is no other endowed scholarship or fellowship. Stipend, income of fund, not to exceed $400 a year. Applications should be filed by March 1st with the President of the University.

University Scholarships. A fixed sum of money is made available each year by the Trustees for the aid of students in all departments of the School of Higher Studies. Awards are made by the President, in consultation with the heads of the various departments. Applications should be filed by March 1st with the President of the University.

Vanderbilt (Virginia Fair) Fellowship. Founded 1929, by Mrs. Wm. K. Vanderbilt. Available in the Johns Hopkins University School of Medicine for the study of ophthalmology. Open to men and women approved by the Professor of Ophthalmology. Stipend, $1200 to $1500 a year. Applications may be filed at any time with the Professor of Ophthalmology, Johns Hopkins Hospital, Baltimore, Md.

Vogeler (Charles A. W.) Memorial Archaeological Fellowship. Founded 1919, by Charles A. W. Vogeler, for study of Greek archaeology. Open to men and women with the A. B. degree. Stipend, income of $5000 and remission of tuition fees. The fellowship may be held in any place that the department may see fit to assign it. Applications should be filed by March 1st on special form furnished by the Scholarship Committee.

KALAMAZOO COLLEGE, Kalamazoo, Mich.

Upjohn Research Scholarship in Chemistry. One or more. Founded by the Upjohn Company. Open to men and women graduates of this College, recommended by the Department of Chemistry. Stipend, $750 a year.

KANSAS, UNIVERSITY OF, Lawrence, Kans.

Boylan Fellowship in Surgery. Established by Mrs. Nellie S. Boylan, who left a bequest of $60,000 for a fellowship in surgery at St. Margaret's Hospital. Stipend, $1500.

KANSAS STATE AGRICULTURAL COLLEGE, Manhattan, Kans.

Applications should be filed by March 1st and not later than April 1st with Chairman, Graduate Council of the College. Special application form furnished.

Graduate Assistantships. Seven. Open to men and women with a bachelor's degree from a standard college or university. Stipend, $270 to $500 a year; ten to eighteen hours per week required in service.

Research Assistantships. Twelve. Open to men and women who have a bachelor's degree from a standard college or university. Stipend, $270 to $500 a year; ten to eighteen hours per week required in service.

KENTUCKY, UNIVERSITY OF, Lexington, Ky.

University Scholarships. Fifteen. Open to men and women with the A. B. degree. Stipend, $200 to $400 a year. Applications should be filed by May 1st with Dean of the Graduate School. Special application form furnished.

KNOX COLLEGE, Galesburg, Ill.

Honnold (William L. O.) Fellowship. Not to exceed two annually. Established 1931, by William Lincoln Honnold for graduates of Knox College. Available to men and women for study in any American university or abroad. Stipend, $500 to $1500 a year.

KOSCIUSZKO FOUNDATION, 149 East 67th St., New York, N. Y.

Kosciuszko Foundation Scholarships. Six. Founded 1925. Open to men and women who are graduate students from Polish universities, between the ages of twenty-three and thirty-five, who have ability to do independent work and have good moral character, good health, adaptability and a knowledge of English. Available at any American university or industry for research in applied sciences, especially in business and industry. There are two or three scholarships for American students to study in Polish universities. Applications should be filed with the Foundation. Special application form furnished.

LABORATORY OF ANTHROPOLOGY, Santa Fe, N. M.

Fellowships for Training in Anthropological Field Method. 12 to 15 annually. Established 1929, by the Rockefeller Foundation. Available normally in ethnology, archaeology, linguistics and physical anthropology. Open to men and women who are graduate students fitting themselves for a professional career in anthropology. Applications must be made on behalf of the student by the chairman or the head of the department in which he is carrying on his graduate work. Available at designated field headquarters, normally within the borders of the United States. Applications should be filed not later than March 15th, on special blank furnished, with Dr. Alfred M. Tozzer, Chairman, Committee on Scholarships for the Laboratory of Anthropology, Harvard University, Cambridge, Mass.

LAFAYETTE COLLEGE, Easton, Pa.

Hart Fellowship. Founded by friends of Dr. Edward Hart, 1922. Open to men with collegiate degree, B. S. in chemistry or its equivalent, with aptitude for research. Available for research in chemistry in Lafayette College. Stipend, $500 a year. Applications should be filed by March 15th with Eugene C. Bingham, Lafayette College.

LAKE ERIE COLLEGE, Painesville, Ohio.

Wilcox (Eliza H.) Fellowship for Graduate Study. Founded by Eliza Wilcox, 1917. Open to women who are graduates of this College for study in this country or abroad. Stipend, $300 a year. Applications should be filed by May 15th with the President.

LANKENAU HOSPITAL, Corinthian and Girard Avenues, Philadelphia, Pa.

McNeil (Robert) Fellowship. For work in the physical chemistry of certain sulfur compounds. Stipend, $1200 a year.

Squibb (E. R.) and Sons Fellowship. For fundamental research. Stipend, $1800 a year (1933).

Grants have been made by the Wagner Free Institute of Science of $1000 a year for chemical research (from the Leffmann Fund), and by the International Cancer Research Foundation of $12,000 a year for biological investigations of growth. All of this money is used to keep workers as long as possible on the problem of the chemical factors concerning cell multiplication.

LEHIGH UNIVERSITY, Bethlehem, Pa.

Archer-Daniels-Midland Company and William O. Goodrich Company Research Fellowships in the Technology of Linseed Oil. Four. Holders are expected to devote half-time to such research work as may be assigned them, and the other half to graduate study leading to the master's degree. Stipend, $600 to $900 a year.

Baldwin (C. Kemble) Research Fellowship in Aeronautics. Founded 1929, by Mrs. C. Kemble Baldwin as a memorial to her husband. Appointment made from time to time as the income from the fund becomes sufficient to pay $750 a year for each of two years. Available for research in any field of pure or applied science having a direct bearing on the advancement of mechanical flight. Holder is expected to devote half-time to such research work as may be assigned him and the other half to graduate study leading to the master's degree. Original amount, $10,000. Present amount, $12,029.

Brink (Lawrence Calvin) Research Fellowship in Civil Engineering. Founded in 1929 by Mrs. Belle Y. Brink as a memorial to her husband. The holder is expected to devote half-time to such research work in the field of civil engineering as may be assigned to him and the other half to graduate study leading to the master's degree. Present amount, $10,000. Stipend, $600 a year.

Byllesby (Henry Marison) Research Fellowships in Engineering. Founded 1926, by Mrs. Henry Marison Byllesby. Two. Open to men who are graduates in science or engineering from a reputable institution and who are qualified to pursue work for a master's degree. Research is to be concerned with the work of the public utilities. Appointment is for two years of ten months each. Half-time is to be given to research and half-time to graduate study leading to a master's degree. Problems to be investigated must be approved by the Chief Engineer of the H. M. Byllesby Corporation. Original amount, $40,000. Present amount, $39,300. Stipend, $750 a year and freedom from University fees.

Eavenson and Levering Research Fellowship. Holder is expected to devote half of his time to such research work in the field of the technology of wool as may be assigned to him, and the other half to graduate study leading to the master's degree. Stipend, $750 a year.

Hoppes (Garrett Linderman) Research Fellowship in Civil Engineering. Established in 1932 through bequest of Mrs. Maria B. Hoppes in memory of her son. The holder is expected to devote half time to such research work in the field of civil engineering as may be assigned to him, and the other half to graduate study leading to the master's degree. Original amount, $10,000. Present amount, $9497. Stipend, $600 a year.

Hunt-Rankin Leather Company Research Fellowships. Two. Holders are expected to devote half time to such research work in the field of leather technology as may be assigned them, and the other half to graduate study leading to the master's degree. Stipend, $600 a year.

Institute of Research Research Fellowships. Given occasionally to assist one of the departments in the promotion of some important investigation. Stipend is indefinite. It may vary from $600 to $750 a year for two years of ten months each.

New Jersey Zinc Company Research Fellowship. Established 1923, for research in any field of science and technology. Holder is expected to devote half-time to such research work as may be assigned him and the other half to graduate study leading to the master's degree. Present amount, $15,000. Stipend, $600 a year for two years of ten months each.

Packard (James Ward) Fellowship in Electrical or Mechanical Engineering. Established 1928, through bequest of James Ward Packard. Holder is expected to devote half-time to such research work as may be assigned him and the other half to graduate study leading to the master's degree. Present amount, $20,000. Stipend, $750 a year.

Ullman (Henry Maas) Student Chemistry Foundation Fund. Two fellowships. Founded by Freshmen students with the refunds from their chemical laboratory balances. Stipend, $750 a year.

LINDENWOOD COLLEGE, St. Charles, Mo.

Scholarship. Established 1925, for advanced study. Open to women graduates of this College. Available for study in any American university or abroad. Stipend, $500. Application should be filed on April 1st before graduation.

LONG ISLAND BIOLOGICAL ASSOCIATION, BIOLOGICAL LABORATORY OF THE, Cold Spring Harbor, L. I.

Jones (John D.) Scholarship. One founded by the Wawepex Society. Open to men and women, nominated by the Director of the Laboratory. Available in the Laboratory for research in biology. Stipend, $250 a year. Applications should be filed before April 15th with the Laboratory.

Prime (Temple) Scholarship. One or two. Founded by Cornelia Prime, 1910. Open to men and women, nominated by the Director of the Laboratory. Available in the Laboratory for research in biology. Stipend, $100 a year. Application should be filed before April 15th with the Laboratory.

Rice (Dorothy Frances) Scholarship. One or two. Founded by Oran W. Rice, 1926. Open to women nominated by the Director of the Laboratory. Available in the Laboratory for research in botany. Stipend, $100 a year. Applications should be filed before April 15th with the Laboratory.

LOUISIANA STATE UNIVERSITY AND AGRICULTURAL AND MECHANICAL COLLEGE, Baton Rouge, La.

Graduate Assistantships. Open to men with a master's degree. Stipend, $900 to $1000 a year; twelve to fourteen clock hours per week required in supervising laboratory.

Teaching Fellowships. Open to men who have received the bachelor's degree. Stipend, $360 a year plus exemption from most university fees; eight hours per week required in supervising laboratory.

LOUISVILLE, UNIVERSITY OF, Louisville, Ky.

Paint, Oil and Varnish Fellowship. Founded 1922, by the Louisville Paint, Oil and Varnish Club, for study in the field of chemistry. Open to men and women, graduates of a college, who have made a very high mark in chemistry while in college. Available for study in the University of Louisville. Stipend, $300 a year. Applications should be filed by March 1st.

Research Assistantships in Medical School. Eight. Open to men and women showing promise in the field of medicine. Stipend varies with experience and amount of time devoted to the work.

Speed (J. B.) Fund Graduate Scholarship. Founded 1922, by Mrs. Hattie B. Speed for graduate work at any institution for higher education within the United States. Open to men and women. Stipend, $250 a year. Application should be filed in second semester on special form furnished.

Teaching Fellowships. Two. Awarded on recommendation of the Director and Faculty of the Graduate School. Stipend, $250 a year.

MAINE, UNIVERSITY OF, Orono, Maine.

Graduate Fellowships. Three. Awarded on a competitive basis by a committee of the Faculty of Graduate Study. Stipend, $500 each. Applications should be made to the Dean before April 1st.

Maritime Provinces Graduate Scholarships. Three—one in each of the colleges of the University. Founded by the Board of Trustees. Open to graduates of the colleges and universities of the maritime provinces of Canada. Stipend, one year's tuition.

Trustee Graduate Scholarships. Four—one in each of the three colleges and one in the School of Education. Stipend, one year's tuition. Open to graduates of the University.

Trustee Scholarships. Five. Open to men and women of the senior class from each of the colleges of the University. Stipend, one year's tuition. Applications should be filed by April 1st with Dean of Graduate Study.

MARINE BIOLOGICAL LABORATORY, Woods Hole, Mass.

Crocker (Lucretia) Scholarships. Open to teachers in Boston. Use of a table for research. Supported by income of a fund established by friends of the Laboratory in Boston.

MARYLAND, UNIVERSITY OF, College Park, Md.

Applications should be filed not later than May 15th with the Dean of the Graduate School. Special application form furnished.

Emerson (Isaac E.) Fund. Founded by Captain Isaac E. Emerson, to establish and maintain a chair in biological testing and drug assaying in the School of Pharmacy, and a fellowship in pharmacology in the School of Medicine, with annual support of $4500 for the former and $1500 for the latter. Applications should be sent to Board of Regents, University of Maryland, J. M. Dennis, Treasurer, Union Trust Building, Baltimore, Md.

Fellowships. Seventeen. Open to men and women of superior scholarship. Stipend, $400 a year; ten to twelve hours per week required in service.

Graduate Assistantships. Twenty-four. Open to men and women of superior scholarship. Stipend, $800 a year; half-time required in service.

MASSACHUSETTS GENERAL HOSPITAL, Boston, Mass.

Dalton Scholarships. One to three. Open to either internes of the General Hospital or male graduates of a regular American medical college. Devoted to investigation in the science of medicine; the nature of the work proposed to be prosecuted shall be designated by the candidate. Stipend, $1000. Scholarship begins September 15th. Applications should be made to Director of the Hospital.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, Mass.

All applications for graduate scholarships and fellowships should be sent by March 1st to the Dean of the Graduate School. Special application form furnished. The Committee on the Graduate School allocates awards from funds placed annually at its disposal. The grants vary from $500, covering tuition, to $1500 in the case of certain fellowships established for specific purposes.

Austin Fund. Founded by Edward Austin, 1899. About $18,000 available annually. Scholarships open to men and women who are graduate students working for master's or doctor's degree. Stipend, usually $500 a year, larger or smaller at discretion of the Committee.

Austin Research Fellowship. Founded by Edward Austin, 1909. Open to men and women who are graduate students working for a doctor's degree. Awarded only to those who have been in residence at M. I. T. Available for study at the Institute or abroad. Stipend, $1000 a year.

Bolles (William Sumner) Fund. Founded by Wm. P. Bolles, 1924. Open to men and women who are graduate students of high scholastic attainments, character, ability or promise. Available for study either in this country or abroad. Stipend, $1100 a year.

Brown (Malcolm Cotton) Fund. Founded by Charles A. and Caroline C. Brown, 1922. Open to men who are graduates of senior class in course in physics at the Institute. Available for study in physics at the Institute or abroad. Stipend, $1000 a year. Not available at present.

Collamore Fund. One or two scholarships. Founded by Helen Collamore, 1916. Open to women who are graduate students working for a master's or a doctor's degree. Available in this Institute. Stipend, $500 a year.

Dalton Fund. Founded by Charles H. Dalton, 1896. Open to men who are graduates of the Institute. Available in this Institute for research in chemistry, especially textile chemistry. Stipend, $300 a year.

Institute of Technology Graduate Scholarships. Open to men and women of high scholastic standing in undergraduate and subsequent study. Available only in this Institute. Stipend, tuition.

Moore Scholarship Fund. Founded by Mrs. F. Jewett Moore, 1914. Open to men and women who are graduates in organic chemistry at this Institute. Available for research in organic chemistry in Europe. Stipend, $1500 a year.

Perkins (Willard B.) Fund. One every fourth year. Founded by Willard B. Perkins, 1898. Open through competition to men students in architectural department of the Institute. Available abroad for the study of architecture. Stipend, $1000 a year.

Proctor (Redfield) Traveling Fellowship. For study in an English university. Open to men who are graduates of or graduate students at the Institute. Stipend, $1500. Not an endowed fellowship, but renewed from year to year. Not yet determined whether it will be available in 1934-35.

Rogers (Henry Bromfield) Fund. Variable number, usually two. Founded by Anna Perkins Rogers, 1921. Open to women who are graduate students. Available in this Institute. Stipend, $500 a year.

Russell (Richard Lee) Fund. Founded by Theodore E. Russell, 1904. Open to men who are students of high standing in the Department of Civil Engineering. Available in this Institute for research in civil engineering. Stipend, $150 a year.

Saltonstall (Henry) Scholarship Fund. Founded by Henry Saltonstall, 1901. Open to men and women who are pursuing advanced courses at the Institute. Stipend, $500 a year.

Savage (James) Fund. Founded by James Savage, 1873. Open to men and women who are graduate students of high scholastic standing. Available in this country or abroad for general scientific study. Stipend, $500 a year.

Swett (Susan H.) Fund. Founded by Susan H. Swett, 1888. Open to men and women who are graduate students pursuing advanced study at the Institute. Stipend, $500 a year.

Textile Research Fellowship. Founded by the Arkwright Club, 1926. Open to men who are graduate students prepared to undertake research work in the field of textile chemistry or engineering. $1000 available.

Traveling Fellowship in Architecture. Competitive and open to men and women students in the Department of Architecture of the Institute. Available for the study of architecture abroad. Stipend, $1500 a year.

Verges (Louis Francisco) Scholarship. Founded by Caroline A. Verges, 1924. Open to men and women who are graduate students. Available in the Institute for research in the sugar industry or civil engineering. Stipend, $500 a year.

Whitney (Jonathan) Scholarships. Approximately 40 at present. Founded by Mrs. Frances B. Greene, 1912. Open to men and women who are poor and deserving, good students and prepared to carry on graduate work. Available in this Institute. Stipend, $500 a year.

MASSACHUSETTS STATE COLLEGE, Amherst, Mass.

Applications should be filed with the Director of the Graduate School, Massachusetts State College. All fellowships are open to men and women with appropriate training and holding the bachelor's degree from a recognized college or university.

Alvord Endowed Dairy Fellowship. Founded 1915, by Henry E. Alvord, for research in dairying. Stipend, $60 a month for half-time service.

American Cranberry Exchange Commercial Research Fellowship, for the study of the nutritive value of cranberries, processing, etc. Stipend, $85 a month.

Eastern States Farmers' Exchange Commercial Fellowship, for research in agronomy. Stipend, $60 a month for half-time service.

Hazel-Atlas Commercial Fellowship, for research on glass containers for food products. Stipend, $50 a month.

Institutional Fellowships (formerly known as Graduate Assistantships). Eighteen. Available in the fields of physical and biological sciences, agriculture, horticulture and social sciences for teaching and research. Stipend, $60 a month for half-time service.

Russia Cement Commercial Fellowship, for study of the nutritive value of fish meal. Stipend, $60 a month.

United States Biological Survey Fellowship, for the study of the use of the red squill in the control of rodents. Stipend, $50 a month.

MELLON INSTITUTE OF INDUSTRIAL RESEARCH, University of Pittsburgh, Pittsburgh, Pa.

Fellowships in the Department of Pure Research. Usually awarded to Doctors of Philosophy. A limited number of fellowships and assistantships in this department are in operation. Investigations are carried on in pharmaceutical chemistry, in the field of synthetic organic medicinals and in the chemistry of the carbohydrates.

Individual Industrial Fellowships. Usually awarded to Doctors of Philosophy, or, in certain cases, to holders of the master's degree. An Individual Industrial Fellowship utilizes the services of one research chemist or engineer (with assistants when necessary), who is responsible directly to the executive staff of the Institute. Supported by industrial associations and companies. There are forty-one fellowships; the annual foundation sums covering all expenses of the specific researches for which they are donated, including salaries, range from $5000 to $8000. The list of the fellowships in operation each year is published with the abstract of the Annual Report of the Director in the News Edition of Industrial and Engineering Chemistry (e. g., 12, no. 8, 141 (1934).)

Multiple Industrial Fellowships. Usually awarded to Doctors of Philosophy, or, in certain cases, to holders of the master's degree. A Multiple Industrial Fellowship utilizes the services of one or more research men (Junior Fellows) under the direction of a Senior Fellow, who in turn is responsible to the executive staff of the Institute. Supported by industrial associations and companies. Fourteen fellowships; the annual foundation sums covering all expenses of the specific researches for which they are donated, including salaries, range from $8000 to $60,000. The list of the fellowships in operation each year is published with the abstract of the Annual Report of the Director in the News Edition of Industrial and Engineering Chemistry. (e. g., 12, no. 8, 141 (1934).)

Booklets descriptive of the Institute's research procedure are sent gratis to all interested persons upon direct request.

MEMORIAL HOSPITAL, 2 West 106th St., New York, N. Y.

Clinical Fellowships in the Study and Treatment of Cancer. Eight. Founded 1927 by John D. Rockefeller, Jr., for study of cancer. Open to men who have the M. D. degree and two years' training in surgery or its equivalent in other postgraduate fields. Available for work in Memorial Hospital. Stipend, $1200 to $2500. Applications should be filed in January or June with Dr. Lloyd F. Craver at above address.

MICHIGAN, UNIVERSITY OF, Ann Arbor, Mich.

Fellows and Scholars do not pay the annual tuition fee and are not called on for instructional duties.

Booth (George G.) Traveling Fellowship. Founded 1923, by George G. Booth, for the study of architecture abroad. Holder must be graduate of the College of Architecture of the University of Michigan, or shall have been in residence for and have substantially completed the last two years of the four year program, and must not be more than thirty years of age. Award is made on basis of studest's general record and a competition in design. Stipend, $1200 a year. Not available for 1933-34.

Braun (Carl) Fellowship. Founded by Mrs. Elsie Braun, Toledo, Ohio, 1913. Open to men and women of high scholarship and ability to do graduate work. Available for study in any field. Stipend, $500 a year. Applications should be filed by March 1st with Graduate School. Special application form furnished.

Cole (Emma J.) Fellowship in Botany. Founded by the estate of Emma J. Cole, 1910. Open to men and women who have ability to do graduate work in botany. Stipend, $400 to $600 a year. Applications should be filed by March 1st with Graduate School. Special application form furnished.

duPont Fellowship in Chemistry. Founded by the duPont Company, 1918. Open to men who have ability to do graduate work in chemistry. Stipend, $750 a year. Applications should be filed by March 1st with the Graduate School through the Department of Chemistry.

Fisheries Research Fellowships. In 1931-32 about six fellowships in fisheries research were provided by the Michigan Division of the Izaak Walton League of America and two additional fellowships were offered by the Institute for Fisheries Research. These involve both field and laboratory studies on some practical fishery problem in Michigan. The stipend varies from $400 to $1200 a year. Applications should be filed by March 1st with the Graduate School through the Museum of Zoology.

Harris (William P., Jr.) Fellowship. Founded 1928, by William P. Harris, Jr. Open to men and women for study of mammalogy in the University of Michigan. Stipend, $600 a year. Holders are nominated by the Museum of Zoology and confirmed by the Executive Board of the Graduate School. Applications should be filed by March 1st on special form furnished by the Graduate School.

Hinsdale (Edwin C.) Fellowship. One or more. Founded by estate of Genevieve Hinsdale, 1921. Open to men and women who have ability to do graduate work. Available in the Museum of Zoology. Stipend, $600 a year. Applications should be filed by March 1st with the Graduate School through the Museum of Zoology.

Lawton Fellowship in Astronomy and Mathematics. Founded by the estate of Francis Lawton, 1919. Open to men and women who have ability to do graduate work. Available primarily for research in astronomy. Stipend, $200 to $400 a year. Applications should be filed by March 1st with the Graduate School through the Observatory, University of Michigan.

Michigan Gas Association Fellowship. The Michigan Gas Association has maintained a fellowship in gas engineering continuously since 1900 with the exception of the War period. The stipend is $750 a year. Applications should be filed by March 1st with the Graduate School through the Department of Chemical Engineering.

Newcombe (F. C. and Susan Eastman) Fellowship. Founded by F. C. and Susan Eastman Newcombe for study of plant physiology. Open to men and women. Stipend, $600 to $1800 a year. During the first year the incumbent will be in residence in Ann Arbor, at a stipend of $600. The second year is to be spent abroad, preferably in Germany or France, at a stipend of $1800, and the third year in Ann Arbor at a stipend of $800. Application presupposes that the candidate pledges himself to the three-year program if his scholarship justifies the second and third year appointments. The candidate may work in the special physiology of any group of plants, or with plant material in general physiology. Applications should be filed by March 1st on special form furnished. Nominations are made by the Department of Botany and confirmed by the Executive Board of the Graduate School.

Parke, Davis and Company Fellowship in Pharmacy. Founded by the Company. Open to men who have ability to do graduate work. Stipend, $500 a year. Applications should be filed with the Graduate School through the School of Pharmacy.

Prescott (Albert B.) Fellowship in Organic Chemistry. Founded 1921, by Mrs. Abigail F. Prescott. Open to men and women, nominated by head professor in the subject and confirmed by the Executive Board of the Graduate School. Available in the University of Michigan. Stipend, $200 to $400 a year. Applications should be filed by March 1st on special form furnished.

Stearns (Frederick) and Company Fellowship in Pharmacy. Founded by the Company, 1918. Open to men who have ability to do research work. Stipend, $500 a year. Applications should be filed with the Graduate School through the School of Pharmacy.

University Fellowships. Fifteen to twenty. Open to men and women who have ability to do graduate work. Available for research in all fields. Stipend, $400 to $600 a year. Applications should be filed by March 1st with Graduate School. Special application form furnished.

Upjohn Company Fellowship in College of Pharmacy. Founded 1928, by the Upjohn Company for study of pharmacy in the College of Pharmacy of the University of Michigan. Open to men and women, nominated by the College of Pharmacy and confirmed by the Executive Board of the Graduate School. Stipend, $750 a year. Applications should be filed by March 1st on special form furnished.

Weeks (John E.) Scholarship for Research Work in Ophthalmology. Founded by Dr. John E. Weeks, 1921. Open to medical students only.

Stipend, income from $10,000. Applications should be filed with Dean, Medical School.

Whittier (Angeline Bradford) Fellowships in Botany. Founded by Joseph Whittier, 1903. Open to men and women who have ability to do research work. Stipend, $300 to $500 a year. Applications should be filed by March 1st with the Graduate School through the Department of Botany.

MICHIGAN STATE COLLEGE OF AGRICULTURE AND APPLIED SCIENCE, East Lansing, Mich.

Fremont Canning Company Fellowship. For the study of the nutritive value of certain of their canned products. Amount provided, $3000.

Graduate Assistantships. There are a number of half-time and of quarter-time assistantships in each of the scientific departments of the College. The stipend for the half-time graduate assistant is $600 a year, and for the quarter-time graduate assistant, $300 a year.

Kellogg (W. K.) Bird Sanctuary Fellowship. Founded 1931, by W. K. Kellogg and the Michigan State College, for the study of birds. Open to men with a B. S. degree and high scholastic standing for study in the W. K. Kellogg Bird Sanctuary, Augusta, Mich. Stipend, $600 for year of ten months. Applications should be filed by April 1st with Dr. M. D. Pirnie, W. K. Kellogg Bird Sanctuary, Augusta, Mich.

Mathieson Alkali Company of Niagara Falls, N. Y. Fellowship. For study in the Bacteriology Department of the germicidal value of certain of their chlorine-containing products. Amount provided, $500.

N. V. Potash Export My. Fellowship. Founded 1930, by N. V. Potash Export My., for research in soils. Stipend, $5400 for three years at which time the fellowship is to expire (or when fund is expended).

National Milling Co. Wheat Fellowship. Founded 1929, by National Milling Co., Toledo, Ohio, for studies on soft wheat. Stipend, $960 annually. The fellowship expires in 1935.

MILLS COLLEGE, Mills College P. O., Calif.

Mills College Trustee Fellowships. One each in botany and bacteriology, biology and hygiene, chemistry, physics, and zoology. Open to women with a college or university degree. Stipend, expenses of residence and tuition ($950); eighteen hours per week required in service. Applications should be filed by April 1st with the Chairman of the Committee on Fellowships. Special application form furnished.

Pease (Amelia Ann) Fellowship. Founded 1928, by Annie Pierce Goodhue, for general scientific study. Open to women with a degree and fitness for graduate work. Available only in this College. Stipend, $500 a year. Application should be filed by April 1st for the following September, on special form furnished by the Committee on Fellowships.

Pierce (James Peironnet) Fellowship. Founded 1928, by Annie Pierce Goodhue, for general scientific study in this College only. Open to women with a degree and fitness for graduate work. Stipend, $500 a year. Applications should be filed by April 1st for following September, on special form furnished by Committee on Fellowships.

MILTON COLLEGE, Milton, Wis.

Graduate Scholarship. *See* Wisconsin, University of. Graduate Scholarships.

MILWAUKEE-DOWNER COLLEGE, Milwaukee, Wis.

Graduate Scholarship. *See* Wisconsin, University of. Graduate Scholarships.

MINNESOTA, UNIVERSITY OF, Minneapolis, Minn.

American Creosoting Company Research Fellowship. Founded by the American Creosoting Company in 1931. Established for the purpose of conducting an investigation to determine the laws governing the movement of liquids in wood and effects of moisture change upon the wood substance. At least half time required in service. Stipend, $900 a year. Applications should be filed by May 1st with the Division of Forestry.

American Dry Milk Institute Fellowship. Founded by the Institute, 1929. Open to men and women with a B. S. or M. S. degree. Available in the Division of Agricultural Biochemistry for the study of dry milk. Stipend, $2400 a year; forty-four hours per week required in service. Applications should be filed ordinarily on April 1st with the Division. Special application form furnished.

Andrews (Thomas F.) Fellowship in Geology. Established from the estate of Thomas F. Andrews, the principal to be invested and the income used for this purpose. Approved by the Board of Regents, 1929. $600 has been received and an additional amount is expected at a later date.

Class of 1890 Fellowship. Founded by the Class of 1890 in 1915. Open to men and women who are graduates of the College of Science, Literature and the Arts and of the College of Engineering and Architecture of this University, who have shown distinguished ability and initiative as students and desire to make further preparation for public service. Stipend, $250 a year. Applications should be filed by March 1st with Dean of the Graduate School.

Cloquet Wood Products Fellowship. Founded by Northwest Paper Company, 1925. Open to men who have at least a baccalaureate degree, with a major in chemistry and an interest in chemical utilization or treatment of wood. Available in the Division of Agricultural Biochemistry. Stipend, $1200 a year; half-time required in service. Applications should be filed by June 1st with the Division.

Dairy and Ice Cream Machinery and Supplies Association Fellowship. A gift of $750 to be used for a study relating to the marketing of milk. The fellow is exempt from tuition in accordance with rules of the University. Approved by the Board of Regents, 1932.

Dorr (Caleb) Research Fellowships. Two. Founded by Caleb Dorr, 1919. Open to men and women who are graduates of any acceptable college or university. Awarded on basis of scholarship and prospect of promise of productive research. Holder must devote his whole time during academic year to graduate work in agriculture, forestry or home economics. Stipend, $500 a year and free tuition. Applications should be filed on or before March 1st with Dean of the Graduate School. Special application form furnished.

Dow Fellowship in Chemistry. A gift of $750 to be used to pay the salary of a graduate fellow majoring in chemistry. Approved by the Board of Regents, 1931.

Fellowship in Tuberculosis. A gift of $300 by an anonymous donor, to be used for this purpose. Approved by the Board of Regents, 1932.

Fleischmann Fellowship. The Fleischmann Company in 1921 gave $800 to provide funds for a research as to the effect of yeast on the wheat gluten. This fellowship has been offered several times since the original gift of 1921.

Howard (Albert) Scholarship. Founded by James T. Howard, 1894. Open to men and women who are graduates of the College of Science, Literature and the Arts of this University. Stipend, $240 a year. Applications should be filed on or before March 1st with Dean of the Graduate School.

Lilly (Eli) Company Research Fund. The Eli Lilly Company gave to the University in 1927 $500 to establish a fellowship for the purpose of investigating the physiological effects of ethylene on organisms and on enzyme action. The appointment and expenditure of the funds is handled by the Division of Plant Pathology and Botany and the Department of Pharmacology.

Mayo Foundation Fellowships. One hundred and ninety-three. Founded by the Mayo Foundation. Open to men and women who have a B. S. degree, are graduates of a high-class medical school and have had one year of interneship. Available in this University for research in medicine and surgery. Stipend, $600 a year with annual increases in second and third years; one-half time required in service. Applications should be filed on or before March 1st with Dean of the Graduate School, or Director of Graduate Work, Mayo Foundation, Rochester, Minn. Special application form furnished.

Minneapolis General Hospital Fellowships. A gift of $3500 to cover the appointment of four medical fellows, two surgical fellows and one pediatric fellow. Approved by the Board of Regents, 1931.

Minnesota State Pharmaceutical Association Fellowship. Founded 1929, by the Association. Open to men and women with a B. S. degree in pharmacy, twenty-one years of age or more, who are residents of Minnesota. Available for study in the College of Pharmacy. Stipend, $500 a year. Applications should be filed by May of each year with the Dean.

Pillsbury Flour Mills Company Fellowship. A gift for the purpose of investigating the fundamentals of biochemistry of milling technology as they may relate to the properties and characteristics of the raw materials of milling or cereals, milling practices and the utilization of flour and cereal mill products in baking and other industries.

Shevlin Fellowships. Four. Founded by Thomas Shevlin, 1909. Open to men and women who are graduates of any acceptable college or university. One available in each of the following: School of Chemistry; Agriculture; Medicine; College of Science, Literature and the Arts. Stipend, $500 a year. Applications should be filed by March 1st with Dean of the Graduate School. Special application form furnished.

University Assistantships (Teaching assistantship and assistantship). Open to men and women graduates of any acceptable college or university. The following are available in the university departments: agriculture and home economics, forty; astronomy, one; botany, eleven; chemistry and chemical engineering, thirty-two; geology and mineralogy, four; mathematics, four; physics, fifteen; psychology, ten; zoology, sixteen. Stipend, $225 to $1200 a year with remission of tuition in Graduate School; two-tenths to eight-tenths of time required in service. Applications should be filed by March 1st with Dean of the Graduate School. Special application form furnished.

University Fellowships in Engineering. Open to men who are graduates of any acceptable college or university. There are two teaching fellowships in electrical engineering, and two Engineering Experiment Station Research Fellowships. Stipend, $600 a year and free tuition in Graduate School; one-half time required in service. Applications should be filed on or before March 1st with Dean of the Graduate School. Special application form furnished.

University Fellowships in the Medical School. Sixteen fellowships and seventeen assistantships, are available for research in medicine and surgery. Stipend, $800 a year; one-half time required in service. Applications should be filed on or before March 1st with Dean of the Graduate School. Special application form furnished.

MISSISSIPPI, UNIVERSITY OF, University, Miss.

University Scholarships. Five or six. Available in this University only for the study of chemistry. Open to men and women with A. B. or B. S. degree. Stipend, $275 a year. Applications should be filed with Dean of Graduate School before June 1st, though they are some times received later. Special application form is furnished but is not necessary.

MISSOURI, UNIVERSITY OF, Columbia, Mo.

Applications for all fellowships, except when otherwise noted, should be filed by March 1st with the Dean of the Graduate School. Special application form furnished.

Agricultural Research Fellowships. Founded 1896. Open to men and women with a master's degree or more, who are under forty and have given proof of ability to do successful research. Available in this University for research in agriculture. Stipend, $600 a year.

Agricultural Research Scholarships. Founded 1896. Open to men and women with a bachelor's degree or more, who are under forty. Available in this University for study in agriculture. Stipend, $300 a year.

Gregory Fellowships. Founded by Charles R. Gregory, 1914. Open to men and women with a master's degree or more, who are under forty. Available in this University, and occasionally abroad, for graduate study. Stipend, $600 a year.

Gregory Scholarships. Founded by Charles R. Gregory, 1914. Open to men and women with a master's degree or more, who are under forty. Available in this University, and occasionally abroad, for graduate study. Stipend, $300 a year.

Teaching Fellowships. Founded 1925. Open to men and women with a bachelor's degree, who are under forty. Available in this University for graduate study. Stipend, $500 to $600 a year; five hours per week required for teaching.

University Fellowships. Founded 1896. Open to men and women with a master's degree or more, who are under forty. Available in this University, and occasionally abroad, for graduate study. Stipend, $600 a year.

University Scholarships. Founded 1896. Open to men and women with a master's degree or more, who are under forty. Available in this University, and occasionally abroad, for graduate study. Stipend, $300 a year.

MISSOURI BOTANICAL GARDEN, St. Louis, Mo.

Lackland (Rufus J.) Fellowships. Established 1909 from the Estate of Henry Shaw. Annually available for research, instruction and these fellowships, $25,000.

MISSOURI SCHOOL OF MINES, Rolla, Mo.

School of Mines—Bureau of Mines Research Fellowship. Established 1921, for study and research in the mineral industry. Open to men with the B. S. degree. Available only in this School. Stipend, $800 for ten months period. Application should be filed, on special form furnished, not later than June 1st with the Director.

MONTANA STATE COLLEGE, Bozeman, Mont.

Walsh Research Fellowship. Founded 1927, by the late Senator T. J. Walsh, for general scientific study in agriculture. Open to both men and women who are college graduates. Stipend, $200 a year. Available for study in any American university. Application should be filed by March 1st.

MONTEFIORE HOSPITAL FOR CHRONIC DISEASES, Gun Hill Road, New York, N. Y.

Lehman (Sigmund M.) Fellowship. Founded 1932, from the estate of Sigmund Lehman. Available to men and women who are members of the hospital visiting staff for study abroad. Stipend, $1650 a year.

Sachs (Alice Goldschmidt) Fellowship. Founded 1933 by the estate of Alice Goldschmidt Sachs. Open to men and women who are members of the hospital visiting staff for study abroad. Stipend, $1175 a year.

Stroock (Hilda Stich) Fellowship. Founded 1927, by Mr. Joseph Stroock. Open to men and women who are members of the hospital visiting staff for study abroad. Stipend, $1175 a year.

MOUNT HOLYOKE COLLEGE, South Hadley, Mass.

Applications should be filed by March 1st with the President. Special application form furnished.

Bardwell Memorial Fellowship. Founded by alumnae of the College, 1899. Open to alumnae of not more than five years' standing. Available in any other American university or abroad for graduate study. Stipend, $1000 a year.

Class of 1905 Fellowship. Founded by Class of 1905, Mt. Holyoke College, in 1922. Open to graduates of this College. Available in any other American university or abroad for graduate study. Stipend, $500 a year.

Skinner (Joseph A.) Fellowships. Four, one each in the Departments of Art and Archaeology, Chemistry, History and Political Science and Physics. Founded 1929 by Joseph A. Skinner. Open to graduates of Mount Holyoke College pursuing graduate work at the College or elsewhere in this country or abroad, and to graduates of other colleges, pursuing graduate work at Mount Holyoke. Stipend, $600 a year. Applications should be filed by March 1st with the head of the department concerned.

Woolley (Mary E.) Fellowship. Founded 1905, by Alumnae Association of Mount Holyoke College. Open to graduates of this College. Available in any other American university or abroad for study. Stipend, $1000 a year.

MOUNT SINAI HOSPITAL, 1 East 100th St., New York, N. Y.

Applications should be filed before February of each year with the Chairman, Fellowship Committee.

Blumenthal (George, Jr.) Fellowships. Founded by Mrs. George Blumenthal, 1908. Open to men and women with the M. D. degree. Available in any American university, and occasionally abroad, for study under the direction of the Mt. Sinai Hospital Director of Laboratories. Stipend, $1600 a year.

Brettauer (Dr. Joseph) Fellowship. Founded by "A Friend," 1933. Open to men and women with the M. D. degree. Available in the Mt. Sinai Hospital for research in gynecology. Stipend, $1200 a year. Application should be filed by February 1, 1934.

Escherich (Theodor) Fellowship. Founded 1913. Open to men and women with the M. D. degree. Available in any American university, and occasionally abroad, for study under the direction of the Mt. Sinai Hospital Director of Laboratories. Stipend, $600 a year.

Heineman (Moses) Fellowship. Founded by Moses Heineman, 1914. Open to men and women with the M. D. degree. Available in any American university, and occasionally abroad, for study under the direction of the Mt. Sinai Hospital Director of Laboratories. Stipend, $600 a year.

Hernsheim (Isidore) Fellowship in Chemistry. Donated by Mrs. Addie W. Homan, 1929. Open to men and women. Available at Mt. Sinai Hospital for research in chemistry. Stipend, $1500 a year.

Meyer (Eugene, Jr.) Fellowship. Founded by Eugene Meyer, Jr., 1910. Open to men and women with the M. D. degree. Available in any American university, and occasionally abroad, for laboratory training under the direction of Mt. Sinai Hospital Director of Laboratories. Stipend, $600 a year.

NATIONAL CONFERENCE ON PHARMACEUTICAL RESEARCH, John C. Krantz, Jr., Secretary, 2411 North Charles St., Baltimore, Md.

Fellowship of the National Conference on Pharmaceutical Research. Established 1931. Awarded to students, both men and women, who are graduates of recognized colleges of pharmacy, for pharmaceutical research in any American university in which graduate work in pharmacy is conducted. Stipend, $250 to $500 a year. Application should be filed in March. Special application form furnished by the secretary.

NATIONAL RESEARCH COUNCIL, 2101 Constitution Ave., Washington, D. C.

National Live Stock and Meat Board Fellowships. Two or three. Founded by the National Live Stock Meat Board, 1924. Open to men and women. Available in any American university for the study of the place of meat in the diet. Applications should be filed with Dr. Paul E. Howe, U. S. Bureau of Animal Industry, Washington, D. C.

National Research Fellowships in the Biological Sciences. Average number, thirty. Founded by the Rockefeller Foundation, 1923. Open to citizens of the United States and Canada under thirty-five years of age who have the Ph. D. degree or who have had equivalent training in research. Available in any American university or abroad for study in zoology, botany, anthropology, psychology and fundamental problems of agriculture and forestry. Basic stipend, $1620 for a single Fellow, $2070 for a married Fellow. Applications should be filed before February 1st with the Secretary, Board of National Research Fellowships in the Biological Sciences, National Research Council, 2101 Constitution Ave., Washington, D. C. Special application form furnished.

National Research Fellowships in Medicine. Average number, twenty. Founded by the Rockefeller Foundation, 1922. Open to citizens of the United States and Canada who have the Ph. D. or M. D. degree, or have had equivalent training in research, and are not over thirty-three years of age. Available in any American university or abroad for research in medicine. Stipend, $1800 to $2300 a year. Applications should be filed before February 1st and August 1st with the Secretary, Medical Fellowship Board, National Research Council, 2101 Constitution Ave., Washington, D. C. Special application form furnished.

National Research Fellowships in Physics, Chemistry and Mathematics. Average number, thirty. Founded by the Rockefeller Foundation, 1919. Open to citizens of the United States and Canada under thirty-five years of age who have the Ph. D. degree or who have had equivalent training and who have demonstrated a high order of ability in research. Available in any American university or abroad for study in the subjects mentioned. Stipend, $1600 to $2400 a year. Fellows may give a portion of their time, not more than one-fifth, to teaching of educational value to themselves. Applications should be filed before March 1st with the Secretary, Research Fellowship Board in Physics, Chemistry and Mathematics, National Research Council, 2101 Constitution Ave., Washington, D. C. Special application form furnished.

NEBRASKA, UNIVERSITY OF, Omaha, Neb.

Parke, Davis and Company Fellowships. Four. Established for the study of organic compounds of arsenic. Stipend, $500 each.

Resident Fellowships in the College of Medicine. Seven. Open to men and women with a baccalaureate degree and basic medical sciences, for study in this University. Stipend, $500 a year. Application should be filed not later than April.

Squibb (E. R.) and Sons Fellowship. For research in the Department of Pharmacology.

NEURO-PSYCHIATRIC INSTITUTE AND HOSPITAL, 200 Retreat Ave., Hartford, Conn.

Fellowships. Two. In connection with Columbia University, the Institute offers two fellowships, one in psychiatry and one in neuro-psychiatry.

NEW HAMPSHIRE, UNIVERSITY OF, Durham, N. H.

Makepeace (A. D.) Company Fellowship, maintained under the direction of the Crop Protection Institute at the University of New Hampshire for methods of extraction of pyrethrum and utilization of the same.

NEW MEXICO, UNIVERSITY OF, Albuquerque, N. M.

The University maintains one graduate fellowship in biology, one in archaeology and one in mathematics. Stipend, $400 in nine equal monthly installments. Applications should be filed with the President.

NEW YORK ACADEMY OF MEDICINE, 2 East 103rd St., New York, N. Y.

Bowen (Alexander Cochran) Scholarships. Two. Established 1930, by Elizabeth Cochran Bowen. Open to men and women who are graduates of a medical school and recent internes in a New York City hospital which accepts charity patients, who would be unable to undertake further study without assistance. Available for study in clinical medicine or surgery in any of their branches for one or two years in foreign countries. Stipend, $1900 a year. Fund is available from year to year at option of donor. Applications should be filed in early spring with the Committee on Medical Education of the New York Academy of Medicine. Meeting generally held in May or June to interview candidates and make selections.

NEW YORK STATE COLLEGE OF FORESTRY AT SYRACUSE UNIVERSITY, Syracuse, N. Y.

Graduate Fellowships. Fifteen in 1933-34. Open to men who have bachelor's degree in forestry, for study in this College. Stipend, $500 a year. Applications should be filed on special form furnished prior to March 1st with the Chairman of the Graduate Committee.

NEW YORK UNIVERSITY, New York, N. Y.

Bryant (Joseph D.) Medical Scholarship. Founded by Dr. Joseph D. Bryant, 1914. Open to men and women (preferably to an applicant from

Norwich, N. Y.). Available in the University and Bellevue Hospital Medical College for study of medicine. Stipend, about $200 a year. Applications should be filed with the Dean, University and Bellevue Hospital Medical College, 477 First Ave., New York, N. Y.

Bull (Richard H.) Graduate Scholarship. Founded by Professor Richard H. Bull, 1890. Open to men and women for graduate study in this University. Stipend, about $50 a year. Applications should be filed with the Executive Secretary, Graduate School, New York University, Washington Square, New York, N. Y.

Bullowa (Mary) Scholarship. Founded by Ralph James M. Bullowa, 1928. Awarded with the approval of the faculty of the Medical College to either men or women. Available at the University and Bellevue Hospital Medical College for study in medicine. Stipend, depends upon annual gift. Applications should be filed as in Bryant Medical Scholarship.

Class of 1890 Scholarship. Founded by the Class of 1890 (1905 and 1925). Preference given to candidates nominated by the Class of 1890. Available in the University College of Arts and Pure Science, College of Engineering or the Graduate School for graduate study. Stipend, $100 to $165 a year. Applications should be filed with the Dean of the School or College in which scholarship is desired.

Department of Architecture Tuition Scholarship. A tuition scholarship is available for a student pursuing studies leading to the master's degree. Applications should be filed with the Dean, College of Fine Arts, 250 E. 43rd St., New York, N. Y.

Duryea Fellowship. Founded by Samuel Bowne Duryea, 1895. Open to men who are members of the graduating class and who have made a high standing in the undergraduate course in engineering. The appointee must register as a candidate for the engineer's degree and serve as an assistant in the College of Engineering for one year. Stipend, about $200 a year. Applications should be filed with the Dean of the College of Engineering, New York University, University Heights, New York.

Graduate Scholarships for Graduates of Ohio Colleges. Certain tuition scholarships are available to graduates of colleges located in the State of Ohio. Applications should be filed with the Executive Secretary, Graduate School, New York University, Washington Square, New York, N. Y.

Herter (Christian A.) Research Scholarship. Founded by Dr. Christian A. Herter, 1903. Open to men and women who are graduates or undergraduates and who have demonstrated aptitude for physiological and chemical research. Available in the Medical College for the encouragement of research in chemical pathology, physiological chemistry or pharmacology. Stipend, $210 a year. Applications should be filed with the Dean, University and Bellevue Hospital Medical College, 477 First Ave., New York, N. Y.

Inman (William H.) Fellowship. Founded by Miss Millie Lee Inman, 1890. Open to men who have completed the course in the University College of Arts and Pure Science or the College of Engineering, whose scholarship places them in the upper third of the class and whose attainments are such as will qualify them, in the judgment of the faculty, to pursue advanced studies in science. Applicant must be enrolled as a candidate for the master's degree in the Graduate School. Stipend, $175 a year; must serve for one year as a demonstrator or assistant in the laboratory of analytical chemistry. (This condition may, for sufficient reasons, be suspended by action of the faculty.) Applications should be filed with the Executive Secretary, Graduate School, New York University, Washington Square, New York, N. Y.

Remsen Graduate Scholarship. Founded by Robert George Remsen, 1896. Open to men and women. Available in this University for graduate study. Stipend, $35 a year. Applications should be filed with the Executive Secretary, Graduate School, New York University, Washington Square, New York, N. Y.

Sandham (George Anson) Medical Preparatory Fellowship. Founded by Miss Anna M. Sandham, 1922. For the encouragement of students who look forward to the study of medicine. The fund provides an income of $375, which is awarded annually as a fellowship in the Department of Biology. Applications should be filed with the Dean, University College of Arts and Pure Science, New York University, University Heights, New York.

University Fellowships. A limited number of University fellowships of $1000 each are offered to graduate students who are candidates for a higher degree from New York University. Applications should be filed with the Executive Secretary, Graduate School, New York University, Washington Square, New York, N. Y.

NEW YORK ZOOLOGICAL SOCIETY, New York Zoological Park, New York, N. Y.

New York Zoological Society Research Scholarship. Established 1929, for study in comparative anatomy, pathology and parasitology. Open to men and women with an A. B. or B. S. degree. Available for study in any American university. Stipend, $1000 a year.

NEWCOMB COLLEGE, New Orleans, La.

Four fellowships are awarded to women with the A. B. or B. S. degree, with special ability in major subject and aptitude for research. Available in Tulane University for graduate study. Stipend, $250 a year; six hours per week teaching or reading work required. Applications should be filed by April 1st with the Dean.

NORTH CAROLINA, UNIVERSITY OF, Chapel Hill, N. C.

Ledoux Fellowship in Chemistry. Founded by Dr. Albert R. Ledoux, 1911. Open to men and women with an A. B. or B. S. degree. Available in this University for research in chemistry. Stipend, $300 a year. Applications should be filed by April with Head, Department of Chemistry.

University of North Carolina Graduate Assistantships. Usually twenty-four for scientific work. Founded 1920. Open to men and women with an A. B. or B. S. degree, satisfactory records and preferably, some teaching experience. Chosen by Head of the department concerned. Stipend, $250 to $750 a year and tuition fees; average of about ten hours per week required in service. Applications should be filed by March 1st with Head of the department concerned, or the Dean of the Graduate School.

University of North Carolina Graduate Scholarships. Number varies. Founded 1920. Open to men and women with an A. B. or B. S. degree and satisfactory previous records. Chosen by the Dean of the Graduate School. Available in this University for graduate study. Stipend, $75. Applications should be filed by March 1st with Dean of the Graduate School. Special application form furnished.

University of North Carolina Teaching Fellowships. Usually about ten for scientific work. Founded 1920. Open to men who have an A. B. or B. S. degree, satisfactory records and promise of ability to carry on advanced work with distinction. Available in the different departments of this University for graduate study. Stipend, $500 a year and tuition fees; number of hours required in service varies but is limited. Applications should be filed by March 15th with Dean of Graduate School.

NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING, Raleigh, N. C.

Assistantship in Farm Management. Stipend, $435 a year.

Research Fellowships. One in Agricultural Experiment Station, Agronomy Department, with stipend of $500 a year; one in botany, with stipend of $600 a year; two in poultry husbandry, one with stipend of $442, and one, $600 a year.

Student Assistantships. One in mechanical engineering, with stipend of $400 a year; one in textiles, with stipend of $200 a year.

Teaching Fellowships. One in botany, with stipend of $442 a year; one in ceramic engineering, with stipend of $500 a year; one in chemistry, with stipend of $528 a year; one in civil engineering, with stipend of $442 a year; one in geology, with stipend of $442 a year; one in physics, with stipend of $442 a year; one in textiles, with stipend of $438 a year.

NORTH DAKOTA, UNIVERSITY OF, Grand Forks, N. D.

Industrial Fellowship. Open to men with bachelor's degree. Available in this University for study of lignite and clay. Stipend, $500 a year. Applications should be filed by April 1st with Director, Division of Mines and Mining Experiments, University Station, Grand Forks, N. D.

NORTHWESTERN UNIVERSITY, Evanston, Ill.

There are in addition to the fellowships enumerated, a number which are based on grants from individual organizations outside the University for the study of specific research problems. These grants may be for one year or several, but they are not endowed and there is no certainty of their continuance.

Assistantships. A number of departments employ college graduates for service on a part-time basis. The stipend varies from $200 to $1000 a year, depending on the preparation of the student and the amount of service required, which is about six to fourteen hours per week. Tuition to the extent of three semester hours is remitted. Available in the Departments of Botany, Chemistry, Geology, Physics, Zoology and in the School of Medicine. Information relative to positions may be obtained directly from the Head of the department concerned. Special application form furnished. Applications should be filed by March 1st.

Corn Products Company Fellowship. Stipend, $600 a year.

Grant Graduate Scholarships in Geology and Geography. Two. Founded 1929. Open to men and women with a bachelor's degree. Available in this University for research in geology and geography. Stipend, $150 a year and graduate tuition. Applications should be filed by March 1st with the Department of Geology and Geography.

Parke, Davis Fellowship. Stipend, $750 a year.

Patten (James A.) Fellowships in Medical Research. Four. Founded by James A. Patten. Open to men and women for medical research in the Medical School. Stipend, $500 a year. Applications should be filed by March 1st with Dean of the Medical School, 303 East Chicago Ave., Chicago. Special application form furnished.

Patten (James A.) Scholarship. Founded by James A. Patten. Open to men and women who have made the best preparation in the College of Liberal Arts in this University and are entering the Northwestern University Medical School. Stipend, $350 a year. Applications should be filed by March 1st with the Dean of the Medical School, 303 East Chicago Ave., Chicago. Special application form furnished.

Research Fellowships in Chemistry. Twenty-two, in amounts from $300 to $800. Open to men with a bachelor's degree (most appointees have a master's degree), superior scholarship and evidence of promise in scientific work. Applications should be filed by March 1st with Chemistry Laboratory. Special application form furnished.

Sage (Rufus H.) Scholarships. Founded by Ellen Sage Bequest, 1911. Open to men and women registered in the College of Liberal Arts, the School of Medicine or the School of Law. The stipends are $100, $150 and $150 in the above schools, respectively. Applications should be filed by March 1st with the school in which the scholarship is to be granted.

Universal Oil Products Fellowship. Stipend, $400 a year.

University Fellowships. Fourteen. Founded 1911. Open to men and women with a bachelor's degree (most students, however, hold a master's degree), superior scholarship and evidence of promise in major field. Available in this University. Stipend, $450 a year and graduate tuition; number of hours per week required in service not to exceed six. Applications should be filed by March 1st with the Graduate School.

Ward (Elizabeth J.) Fellowships. Number varies, usually eight to twelve. Founded by Mrs. Elizabeth J. Ward, 1927. Open to men and women on competitive basis of application. Available in this University for research in medicine. Total income available, $25,000. Applications should be filed by March 1st with the School of Medicine, Ward Memorial Bldg., McKinlock Campus, Chicago.

Ward (Elizabeth J.) Scholarships. Founded by Mrs. Elizabeth J. Ward, 1927. Open to men and women, sophomore, junior, senior or graduate students in the Dental School. Available in the School for research in dentistry. Applications should be filed by March 1st with the Dental School, 303 East Chicago Ave., Chicago.

White (Catherine M.) Scholarships. Two. Founded by Catherine M. White, 1900. Open to men and women with a bachelor's degree; awarded by competition to students in liberal arts subjects and very often go to those majoring in science. Available in this University. Stipend, $150 a year and graduate tuition. Applications should be filed by March 1st with Graduate School. Special application form furnished.

NOTRE DAME, UNIVERSITY OF, Notre Dame, Ind.

Burns (P. C.) Fellowship in Electrical Engineering. Established by a bequest of $25,000, to promote research in the field of electrical engineering.

McCanna (Charles Bernard) Fellowship in Chemistry. Established by a bequest of $10,000. The earned income from this fund is given annually to a graduate student in chemistry who is preparing to become a teacher and has shown special aptitude in chemical research.

Seng (Frank J.) Fellowship in Chemistry. Established by a bequest of $3000. The earned income from this fund is given annually to a graduate student in chemistry who is preparing to become a teacher and has shown special aptitude in chemical research.

Teaching Fellowships. Ten graduate assistantships, paying from $350 to $750 in cash stipends are available in the Department of Chemistry for the support of students doing graduate work. The holders of these assistantships do not pay laboratory fees and supplies for their researches are furnished gratis. In a few instances such assistants also receive free tuition. Appointees give from 8 to 15 hours per week part-time service as laboratory assistants. Applications should be filed before March 1st with the head of the Department of Chemistry. Applicants must be graduates of a recognized college or university, and should have a thorough grounding in physics, mathematics and chemistry.

See also du Pont de Nemours and Company, E. I.

OBERLIN COLLEGE, Oberlin, Ohio.

In general, applications should be filed by March 15th with the Chairman, Committee on Graduate Study. Special application form furnished.

Aelioian Fellowship. One each alternate year. Founded by the Aelioian Society, 1914. Open to Aelioian women who have been graduated from college at least two years. Available in any American university or abroad for general scientific study. Stipend, $1000 a year.

Gilchrist-Potter Prize Fund Fellowship. Founded by Mrs. Ella J. Gilchrist-Potter. Open to women, graduates of Oberlin, with high scholarship record and high promise of usefulness, who are self-supporting and need aid. Available in any American university or abroad for general scientific study. Stipend, $300 a year.

Graduate Fellowships. Six. Founded 1927-1928. Open to men and women with very high scholarship, particularly in major field. Available in this College for general scientific study. Stipend, $500 a year and term bills of $300. In abeyance for the present.

Graduate Scholarships. Twenty. Open to men and women who have had a B plus average in major subject and B general average for four years of undergraduate work. Available in this College for general scientific study. Stipend, $225 (term bills only).

Johnston Fellowship. One each alternate year. Founded by L. L. S. (Literary Society), 1898. Open to Oberlin women members of L. L. S., for general scientific study in any American university or abroad. Stipend, $1000 a year.

Lincoln (Mary MacKenzie) Scholarship. Founded by John C. Lincoln, 1917. Open to women with high attainment in zoology and promise of research ability in this line, who have financial need. Available for summer study at Marine Biological Laboratory, Woods Hole, Mass. Stipend, $50. Applications should be filed by April 1st with C. G. Rogers, Department of Zoology.

Oberlin Scholarship in Zoology at the Marine Biological Laboratory. One for summer study in 1934. Open to men and women with high attainment and promise of research ability in zoology. Available in the Laboratory. Stipend, $100. Applications should be filed by April 1st with R. A. Budington, Department of Zoology.

OCCIDENTAL COLLEGE, Los Angeles, Calif.

Graduate Assistantships. Six to ten. Established at various times through general student aid funds. Open to men and women with a bachelor's degree and a proficiency in special field, i. e., chemistry, physics, geology, zoology, etc. Available in this College. Stipend, $200 to $250 a year. Application should be filed by March 15th with the Dean of the Faculty.

OHIO STATE UNIVERSITY, Columbus, Ohio.

Applications should be filed not later than March 1st on special form furnished by the Dean of the Graduate School.

Battelle Memorial Institute Fellowship. Founded 1931, by Battelle Memorial Institute, for research in metallurgy. Open to men with at least a baccalaureate degree from an approved institution for study in this University. Fellow must devote all his time to graduate work leading to the master's or doctor's degree. Stipend, $600 a year, with exemption from all fixed fees except a matriculation fee of $10.

Graduate Assistantships. About 100. Open to men and women with a baccalaureate degree from an approved institution. Assistantships must give about 12 clock hours per week to assisting in the departments to which they are appointed. Stipend, $450 a year, with exemption from all fixed fees except a matriculation fee of $10. Applications should be sent to Chairman of the department in which the candidate desires to secure an assistantship.

Lord (Nathaniel Wright) Fellowship. Founded 1926, by William Bartlett Calkins, for study in solid fuels. Open to men with at least a baccalaureate degree. Available only in this University. Stipend, $750 a year with exemption from all fixed fees except a matriculation fee of $10.

Robinson (Stillman W.) Fellowship. For study in mechanical, civil or electrical engineering. Open to men with at least a baccalaureate degree from an approved institution. Available only in this University. Fellow must devote all his time to graduate work, one half of which must be research.

University Fellowships. Number varies from year to year, but usually six to twelve. Established 1914 for study in this University only. Open to men and women with a master's degree or the equivalent, not over 35 years of age. Holder must devote his entire time to graduate work and must be studying for the Ph. D. degree. Stipend, $400 a year, with exemption from all fixed fees except a matriculation fee of $10.

University Scholarships. Number varies from year to year. Usually between 15 and 20. Established 1914 for study in this University only. Open to men and women with at least a baccalaureate degree from an approved institution, not over 35 years of age. Holder must devote his entire time to graduate work and must be a candidate for an advanced degree. Stipend, $250 a year, with exemption from all fixed fees except a matriculation fee of $10.

See also du Pont de Nemours and Co., E. I.

OKLAHOMA AGRICULTURAL AND MECHANICAL COLLEGE, Stillwater, Okla.

Fellowships in Chemistry, Botany, Bacteriology, Zoology, and Economics. Twenty-five to thirty-five. Open to both men and women with bachelor's degree, with major in department concerned. Available in this University for study in the subjects noted. Stipend, $40 to $50 a month; 15 clock hours per week required in service. Applications should be filed by March 1st with Head of the department concerned or Dean of the Graduate School.

OKLAHOMA, UNIVERSITY OF, Norman, Okla.

American Gas Association Scholarship. The Association has made available each year the sum of $500 for the support of the Natural Gas Fellowship. Awarded to a student who is an employee or the son of an employee in some field of natural gas engineering, and whose major interest lies in the field of production, transportation, compression, measurement, regulation and utilization of natural gas. All correspondence should be addressed to Professor W. H. Carson, Director of the School of Petroleum Engineering. Applications must be filed on or before March 1st.

Balyeat (Ray M.) Fellowship in Allergy. Founded 1929, by Dr. Ray M. Balyeat, Oklahoma City. Awarded to a graduate student in the department of botany to encourage the study of plant materials which may be factors in the cause of asthma, hayfever and other allergic diseases. Appointment is on an eleven-months basis and is administered in the same manner as university research fellowships. Stipend, $600 a year. Applications should be filed on or before March 1st with the Head of the Department of Botany.

Fellowships in Petroleum Engineering. Founded 1925. Several fellowships in petroleum production and refinery engineering will be available for the year 1934-35. Stipend, usually $600 for the year. Applications should be filed on or before March 1st with Director, School of Petroleum Engineering.

Graduate Assistantships. Open to all graduate students, whether candidates for the master's degree or the doctor's degree. Stipend varies from $200 to $800 a year, with the emphasis on appointments at $300 and $500. The $500 appointments will permit a fully prepared student to meet the requirements for a master's degree in one long session and one summer session. To those graduate students whose training and experience are not sufficient to justify appointment on the same basis as instructors, the stipends vary from $200 to $400, depending upon the nature and amount of service.

Kelly (Howard A.) Fellowship in Museum Field Work. Founded by Dr. Howard A. Kelly of Baltimore, Maryland, 1925. One or more fellowships covering the expenses of graduate students participating in field expeditions under the auspices of the Museum of Zoology and associated organizations. Application should be filed on or before March 1st with the Department of Zoology.

Natural Gas Fellowship. Awarded by the American Gas Association, to a student whose major interest lies in the field of the production, transportation, compression, measurement, regulation and utilization of natural gas. Stipend, $500 a year. Applications should be filed on or before March 1st with the Director, School of Petroleum Engineering.

Phi Gamma Delta Fellowship. Founded by the alumni of this fraternity, residing in Oklahoma, 1925. Open to men. The recipient acts as educational counselor for members of the local chapter. Preference will be given to a member of the fraternity. Stipend, $750 a year; eighteen hours per week required in service. Applications should be filed on or before March 1st with Mr. Frederick B. Owen, Braniff Bldg., Oklahoma City.

Research Fellowships. Six. Founded 1924. Open to men and women who are graduates of recognized universities and colleges. Stipend, $300 to $400 a year; the major department may call upon the student for a limited amount of service. Applications should be filed on or before March 1st with the Dean of the Graduate School. Special application form furnished. (Temporarily discontinued.)

Research Scholarships. Four. Founded 1924. Open to men and women who are graduates of recognized universities and colleges. Stipend, $150 to $250 a year; the major department may call upon the student for a limited amount of service. Applications should be filed on or before March 1st with the Dean of the Graduate School. Special application form furnished. (Temporarily discontinued.)

University Scholarships. Twenty. Founded 1924. Open to men and women who are graduates of recognized universities and colleges. Stipend, remission of tuition. The major department may call upon the student for a limited amount of work. Applications should be filed on or before March 1st with the Dean of the Graduate School. Special application form furnished.

OREGON, UNIVERSITY OF, Eugene, Ore.

Associated Women Students' Foreign Scholarship. Awarded every other year. Established 1923, by the Associated Women Students of the University of Oregon. Applications are placed with the Institute of International Education, New York, by foreign students. The A. W. S. then sends a description of the type of student they would like to secure. The selection is made from applications most nearly meeting that classification. It is available only in the University of Oregon. The stipend includes payment of fees at the University and travel expenses to Eugene, Ore., after the student has arrived in the States. It also includes board and room at the University for one school year and text books used in the course of the study selected.

Graduate Assistantships. Ten. Open to graduates of standard institutions. Graduate assistants give part-time service to the department as assistants in various capacities amounting to not more than twenty hours per week. Sometimes an assistantship is divided between two applicants. In this case, each applicant receives one-half of the stipend and is assigned a smaller number of hours of service. The regular assistantship stipend is from $400 to $500 a year. Appointees are charged a reduced registration fee of $16 a term, and are not allowed to register for more than ten hours of work a term. Applications should be filed before April 1st with the Dean of the Graduate School. Special application form furnished.

Lewis (Ion) Traveling Fellowship. Founded 1930 by Mr. Ion Lewis for the pursuit of architectural studies in the United States or abroad. Open to men and women (usually awarded to men) who are advanced students in architecture, over twenty years and under thirty years of age, who have been or are to be students of the University of Oregon, either as regular or special students. Stipend, $1200 a year. Applications should be filed during the school year on special form furnished by Department of Architecture.

Mu Phi Epsilon Scholarship. Awarded once every three years. Founded 1924, by the American Association of University Women. Open to women with a bachelor's or master's degree or the equivalent, who are residents of the state of Oregon. Advanced study must be done in an American university outside the state of Oregon or in a foreign university. Stipend, $1200 a year. Applications should be filed on special form with Miss E. Ruth Rockwood, Portland Library, Portland, Ore.

OREGON, UNIVERSITY OF, MEDICAL SCHOOL, Portland, Ore.

Jones Research Fellowship in Pathology. Founded 1920, by Dr. Noble Wiley Jones. Stipend, $240 a year.

OREGON STATE AGRICULTURAL COLLEGE, Corvallis, Ore.

Fleischmann Fellowship. A grant of $900 for the year for chemical research on yeast is given by Standard Brands, Inc., of New York, successor to the Fleischmann Company; $750 of this amount is the stipend of the Fleischmann Fellowship. It is awarded to a graduate student and the research is carried on under the direction of the Chemistry Department.

International Friendship Scholarship. The Home Economics Club in 1926 founded a scholarship to be awarded annually to a graduate foreign student to study home economics at Oregon State Agricultural College. The recipient is selected by a committee composed of the executive council of the Home Economics Club, the Dean of the School of Home Economics and a representative of Omicron Nu. Stipend, $500 a year.

Kingery Dermatological Research Fellowship in Chemistry. Established by Dr. Lyle B. Kingery. A graduate research fellowship is awarded for the study of chemical means of combating pathogenic yeast infections. The stipend is $600.

McDonald (Mary J. L.) Fellowship in Reforestation. Founded by Mrs. McDonald of San Francisco. Awarded annually by a committee of the faculty of the Oregon State School of Forestry to a graduate of a recognized school of forestry on the basis of proficiency in forestry studies, personality and demonstrated ability to do independent work.

PACK (CHARLES LATHROP) FOREST EDUCATION BOARD, 1214 16th St., N. W., Washington, D. C.

Pack (Charles Lathrop) Forestry Fellowships. Eight. Ordinarily the fellowships are restricted to men of American or Canadian citizenship; while there are no restrictions as to age, educational status or practical experience, they will be granted usually to those who have finished an undergraduate college course or its equivalent. The stipend ranges from $500 to $1500, though a higher sum may be authorized by the Board in special cases. Appointments may be made for twelve months, or for a longer or shorter period in accordance with the scope of the proposed work. Applications must be made in writing on the form furnished, before the last day of the calendar year, to the secretary.

PENNSYLVANIA, UNIVERSITY OF, Philadelphia, Pa.

Most fellows and scholars are exempt from payment of tuition fees, but must pay matriculation and graduation fees, and must make the usual deposits. Fellows for research are exempt from the payment of all fees and are not required to make the usual deposits. Except when otherwise noted, applications should be filed by March 1st with Graduate School, Bennett Hall, 34th and Walnut Sts., Philadelphia, Pa. Special application form furnished.

Abbott Fellowship in Chemotherapeutic Research. Established for 1933-34 in the Department of Dermatology and Syphilology for the conduct of clinical, or combined laboratory and clinical, studies on the action of arsphenamine and allied compounds in the treatment of disease, especially syphilis.

Bennett (Joseph M.) Fellowships. Two. Founded by Col. Joseph M. Bennett. Open to women with bachelor's degree from an accredited institution, plus at least one year's graduate study and a reading knowledge of two modern foreign languages, preferably French and German. Available in this University. Stipend, $400 a year.

Bok (Edward W.) Fellowship in Clinical Medicine. Founded 1927, by Edward W. Bok, for the support of a fellowship in clinical medicine.

Clark (John Goodrich) Fellowship in Gynecology. Established 1932, under the John G. Clark Memorial Fund, for the support of a fellowship in gynecology.

Dickson (Samuel) Fellowship. Founded by Samuel Dickson. Open to men and women, but preferably men. Elected for two years upon nomination of the Director of the William Pepper Laboratory of Clinical Medicine.

Frazer (John F.) Fellowship. Founded 1887 and 1901. Open to men with bachelor's degree from an accredited institution plus at least one year's graduate study, and a reading knowledge of French and German. Available in this University for research in physics. Stipend, $600 a year.

Frazier (George Harrison) Research Fellowship. George H. Frazier has provided for a research fellowship in surgery for the year 1933-34.

Frazier (Harriet M.) Fellowship for Research in Surgery. Provided for by Mrs. and Mr. John E. Zimmermann.

Girvin (Robert M.) Fellowship. Founded by Dr. John H. Musser, Jr., 1913. Appointment made by Professor of Research Medicine. Stipend, income from endowment. Available in this University.

Godey (Louis A.) and Seeger (Marion Godey) Fellowship in Clinical Medicine. Founded 1926, by the gifts of Mrs. Alan D. Wilson and Mrs. Roland Seeger, and supplemented in 1931 by gifts of Mrs. L. G. McMichael and Mrs. Thomas S. Bradlee, for the support of a fellowship in clinical medicine.

Gynecologic Research Fellowships. Two. Offered under the auspices of the Gynecean Hospital Institute of Gynecological Research. Stipends, $1000 and $3600 a year, respectively.

Harrison (George Leib) Fellowships. Seventeen. Founded in 1895, by Charles C. Harrison. Open to men with a bachelor's degree from an accredited institution plus at least one year's graduate study and a reading knowledge of French and German. Available in this University. Stipend, $600 a year.

Harrison (George Leib) Fellowships for Research. Two. Founded 1895, by Charles C. Harrison. Open to men with a Ph. D. degree. As a general rule, available in this University only. Stipend, $1500 a year.

Harrison (George Leib) Scholarships. Six. Founded 1895, by Charles C. Harrison. Open to men with a bachelor's degree from an accredited institution. Available in this University. Stipend, $200 a year.

Heckscher (Henrietta) Memorial Fellowship in Medical Research. Founded 1913, by Stevens Heckscher. Awarded by the Professor of Medicine for half-time research in clinical medicine in this University.

Hunter and Agnew Fellowships in Surgery. Founded 1924, from funds bequeathed by E. A. W. Hunter. Stipends, $850 and $1800 a year, respectively.

Johnson (Eldridge Reeves) Foundation Scholarships. One scholarship on this Foundation is available each year for graduate students taking a course of study leading to the degree of Ph. D. in biophysics. The holder is required to possess a satisfactory baccalaureate degree and to do full-time work under the direction of the Eldridge Reeves Johnson Foundation for Medical Physics. Stipend, $400 a year and free tuition. Reappointment may be made for a second or third year.

Kent (A. Atwater) Fellowship in Clinical Medicine. Founded 1927, by the gift of A. Atwater Kent, for the support of a fellowship in clinical medicine.

Kirby (F. M.) Fellowship. Founded 1924, by the gift of F. M. Kirby. The fellowship is to be within the domain of surgery, with special reference to physiology, and to be awarded from time to time to holders of the degree of Doctor of Medicine, who shall have completed satisfactorily the required term of interneship in the Hospital of the University of Pennsylvania or at any other hospital acceptable to the Committee in charge of the fellowship. No holder of the fellowship is eligible for reappointment for more than three years.

Lilly (Eli) Fellowship. Provided by Eli Lilly and Company, for a fellowship in the Department of Pediatrics for the continuation of work on convulsant poisons under the direction of Dr. Joseph Stokes, Jr. (For the year 1933-34.)

Matthews (Bishop Paul) Fellowship in Urology. Founded 1928, by Rt. Rev. Paul Matthews, D. D., Bishop of New Jersey. Provides a fellowship of tenure of one or more years, paying a stipend of $100 a month to a graduate in medicine who has completed his hospital service and is pursuing the specialty of urological surgery.

Moore (Bloomfield) Fellowships for Women. Two. Founded by Mrs. Bloomfield Moore. Open to women with a bachelor's degree from an accredited institution plus at least one year's graduate study, a reading knowledge of two modern foreign languages and a declared intention to become a teacher. Available in this University. Stipend, $500 a year.

Moore Graduate Fellowships. Four. The Board of Trustees of the Moore School of Electrical Engineering, upon the recommendation of the Dean of the Moore School, awards four graduate fellowships in electrical engineering. Candidates must hold the degree of Bachelor of Science and must give evidence that a course has been completed in electrical engineering substantially equivalent to the undergraduate course given in the Moore School. Stipend, $400 a year and free tuition.

Morris Arboretum Fellowships. Five. Established 1932, for research in botany. Open to men and women with a bachelor's degree for study in the University of Pennsylvania. Stipend, $1200 a year. Candidates are selected by the Scientific Staff of the Arboretum, nominated to the Administrative Committee of the Arboretum and confirmed by the Advisory Board of Morris Foundation. Applications should be filed before June 1st with the Director, Morris Arboretum, Chestnut Hill, Philadelphia, Pa.

Pennsylvania College of Dental Surgery Fellowship. Offered annually. Holder must possess a college degree, but not necessarily a degree in dentistry. The research undertaken must be upon a subject bearing upon the scientific or clinical problems of dentistry or the allied sciences. Stipend, $1000 a year.

Pepper (Frances Sergeant) Fellowship. Founded by Dr. William Pepper, 1892. Open to women with bachelor's degree from an accredited institution, plus at least one year's graduate study, and a reading knowledge of two modern foreign languages. Available in this University. Stipend, $300 a year.

Porter (Robert Robinson) Fellowship. Founded by Mrs. Harriet C. Prevost, 1912. Available in the John Herr Musser Department of Research Medicine.

Scott (J. Alison) Fellowship. Founded 1929, by sundry gifts to establish a memorial to Dr. J. Alison Scott. Provides for a fellowship in research medicine.

Scott (Thomas A.) Fellowship in Sanitary Science and Hygiene. Open to men and women not more than thirty years of age, who show evidence of a liberal education, including a bachelor's degree, and have a reading knowledge of French and German, chemistry and biology. Available in this University. The primary purpose of the Fellowship is the prosecution, under the direction of the Head of the Department, of special studies relating to the causation and prevention of disease, by the delivery of special lectures bearing upon the subject of investigation and the completion of a thesis. Stipend, $1000 a year.

Special Fellowship in the Department of Physics. The faculty of the Department of Physics have provided for a special fellowship in physics for the year 1933-34, with a stipend of $1000.

Tyndale (Hector) Fellowship. Founded by John Tyndale, 1885. Open to men with a bachelor's degree from an accredited institution, plus at least one year's graduate study and a reading knowledge of French and German. Available in this University for the study of physics. Stipend, $600 a year.

University Fellowships for Research. Open to men and women with the Ph. D. degree. Available in this University. Stipend, tuition.

University Scholarships. Thirty. Open to men and women with a bachelor's degree from an accredited institution. Available in this University. Stipend, tuition.

Wood (George B.) Fellowship in Bacteriology. Provided for the year 1933-34 in the William Pepper Laboratory of Clinical Medicine. Stipend, $1200 a year.

Wood (George B.) Teaching Fellowship in Public Hygiene. Open to men and women who show evidence of liberal education, including the bachelor's degree, and a reading knowledge of French and German, physics, chemistry and biology, who are not more than thirty years of age. Available in this University. Stipend, $700 a year.

Woodward Fellowship in Physiological Chemistry. Founded by George Woodward, 1901. Open to men and women, preferably to men. Holder is selected for a term of two years upon nomination by the Director of the William Pepper Laboratory of Clinical Medicine. Available in this University.

PENNSYLVANIA STATE COLLEGE, State College, Pa.

Elliott Research Fellowship. For research in heat transfer. Open to men only, with a B. S. degree from this College and high standing. Available only in this College. Stipend, $800 a year. Applications should be filed by May 1st on special form furnished by the Dean of Engineering.

Graduate Assistant in Architecture or Architectural Engineering. Three. Open to men only, with a B. S. degree and high standing. Available only in this College. Stipend, $800 a year. Applications should be filed as in above fellowship.

Graduate Assistants in Chemistry and Physics. Twenty-one in chemistry, twelve in physics. Established 1929. Open to men and women with a baccalaureate degree who are candidates for a Ph. D. degree. Two-thirds of the time must be devoted to research. Available only in this College. Stipend, $800 a year. Applications should be filed by February 15th on special form furnished by the Dean of the School of Chemistry and Physics.

Graduate Scholarships. Twelve. Open to men only, with a B. S. degree and high standing for study in architecture and engineering. Available only in this College. Stipend, fees rebated. Applications should be filed by May 1st on special form furnished by the Dean of Engineering.

Graduate Stipend Scholarships. Five. Open to men only, with a B. S. degree and high standing, for study in architecture and engineering. Available only in this College. Stipend, $300 a year. Applications should be filed as in above scholarship.

White (John W.) Fellowships. Three. Established 1924, by John W. White, for general scientific study. Open to men and women who are graduates of this College. Available for study in any American university or abroad. Stipend, $600 a year. Applications should be filed by April 1st with Chairman, Committee on Academic Standards, College Senate, State College, Pa.

PHILADELPHIA COLLEGE OF PHARMACY AND SCIENCE, 43rd St., Woodland and Kingsessing Avenues, Philadelphia, Pa.

Edible Gelatin Manufacturers' Research Society of America Fellowship. Open to men and women who are graduate students for study in this college of problems submitted by the Society. Stipend varies. Applications should be filed any time with the Dean of Science.

French (Clayton) Fellowship. Founded 1914 by Mrs. Mary I. Banks in honor of her father, Clayton French. Restricted to pharmaceutical research in this College. Open to men and women who are graduate students. $400 a year available at this time. The fellowship was started with the sum of $5000, and is being left untouched until it reaches $10,000, at which time it can adequately support a fellowship. The value in September, 1932, was $9760.

Keasbey and Mattison Fellowship. Founded 1920, by Dr. Richard Mattison, for research in pharmaceutical subjects. Open to men and women who are graduate students for study in the College. Stipend equivalent to full tuition. Application should be filed during summer months with the Dean of Science.

Kilmer (F. B.) Research Fellowship. Founded 1923, by Dr. Frederick B. Kilmer and his wife, for research in pharmacognosy and plant chemistry. Open to men and women who are graduate students. Stipend is variable. Entire yield of fund is about $550 annually. Available only in this College. Application should be filed during summer months with the Dean of Science.

Leffmann Research Fund. Founded 1930, by Dr. Henry Leffmann. Restricted usually to pharmaceutical or allied subjects; very often in biology. Open to men and women who are graduate students for study in this College only. Stipend variable. Applications should be filed during summer months with the Dean of Science.

Warner Research Fund. Founded 1929, by Warner and Company, for research in problems submitted by that Company. Open to men and women who are graduate students, for study in this College. Stipend, variable. Applications may be filed at any time with the Dean of Science.

PITTSBURGH, UNIVERSITY OF, Pittsburgh, Pa.

Graduate Assistantships. A number of graduate assistantships are available each year in the various schools of the University. The normal stipend for such an appointment is $700 plus remission of tuition. Each assistant gives aid to a department to the extent of approximately 12 credit hours (20 to 24 clock hours) a week and is permitted to register for a maximum of nine credits (12 credits for each of the final two semesters in which the thesis is written) of graduate work a semester. Those interested should apply in January or February directly to the department concerned.

Graduate Council Scholarships. Twelve. Founded by Graduate Council, 1926. Open to men and women with bachelor's degree. Available in this University. Stipend, free tuition amounting to $282. Applications should be filed by April 1st at 206 State Hall, University of Pittsburgh. Special application form furnished.

Mellon Fellowship. Founded by Mr. R. B. Mellon, 1911. Open to men and women with an M. D. degree or special technical training, for research in pathology. Available in this University. Stipend, $1000 a year. Applications should be filed before July 1st with School of Medicine, University of Pittsburgh.

Mellon Fellowship. Founded by Mr. R. B. Mellon, 1914. Open to men with an M. D. degree. Available in St. Francis Hospital for research in medicine. Stipend, $1200 a year. Applications should be filed before July 1st with School of Medicine, University of Pittsburgh.

See also Mellon Institute of Industrial Research.

POMONA COLLEGE, Claremont, Calif.

Honnold (William L.) Foundation. One or two fellowships. Founded 1930, by William L. Honnold. Unrestricted in subject. Open to men and women who are graduates of Pomona College, for study in any American university or abroad. Stipend, $500 to $1500 a year. Applications should be filed by February 1st with Scholarship Committee.

PRESBYTERIAN HOSPITAL, 620 West 168th St., New York, N. Y.

Harkness (Edward S.) Surgical Fellowship. Founded 1927 by Mr. William Hale Harkness and Mrs. William L. Harkness. The income is used to provide a fellowship in general surgery. Stipend, $1500 a year.

Macy Fellowship. Founded 1933, by Josiah Macy, Jr. Foundation.

Moore (Paul) Surgical Fellowship. Founded 1927, by Mr. Paul Moore. The income is to provide a fellowship in general surgery. Stipend, $1600 a year.

PRINCETON UNIVERSITY, Princeton, N. J.

Fellowships open to men only. Applications should be filed by March 1st with the Dean of the Graduate School. Special application form furnished. Preference given to younger applicants. Holders of fellowships and scholarships are granted free tuition.

Baker (J. T.) Chemical Company Research Fellowship in Analytical Chemistry. Founded by the Company to be granted to an advanced student in analytical chemistry for study in an institution conferring the doctor's degree in chemistry in one of the New England States, New York, Pennsylvania, New Jersey, Delaware or Maryland. The objects are to develop fundamental research in the quantitative estimation of inorganic components as distinguished from routine application of established methods; to encourage such research; and, in general, to develop reliable precise chemical measurement. Stipend, $1000 a year. Ordinarily it will not be awarded to the same candidate for two years in succession.

Class of 1860 Experimental Science Fellowship. Founded by the Class of 1860 in 1870. Available in this University for study of physics or chemistry. Stipend, $800 a year.

Class of 1883 Fellowship. Founded by the Class of 1883 in 1910. Available in this University for the study of politics, physics, chemistry, biology or geology. Stipend, $800 a year.

Cuyler (Theodore) Graduate Scholarship. Founded by C. C. Cuyler, 1902. Available in any department of this University. Stipend, $400 a year.

DuPont Fellowship in Chemistry. Supported by E. I. duPont de Nemours and Company. Available in this University for the study of chemistry. Stipend, $800 a year.

Harvard Fellowship in Chemistry. Founded by one of the Fellows of Harvard University, 1905. Available in this University for the study of chemistry. Stipend, $800 a year.

J. S. K. Mathematical Fellowship. One; frequently a second fellow may be appointed. Founded by a resident of New York City, 1873. Available in this University for the study of mathematics. Stipend, $800 a year.

Jacobus (Porter Ogden) Fellowship. Founded by Mrs. Clara Cooley Jacobus, 1905. Available in this University for study in any department. Stipend, $1400 a year.

MacDonald (Gordon) Fellowship. Founded by Mr. James Speyer, 1908. Available in any department of this University. Stipend, $800 a year.

Maule (Francis Hinton) Biological Fellowship. Founded by Mr. and Mrs. Francis I. Maule, 1901. Available in this University for study in biology. Stipend, $800 a year.

Munn (Charles Allen) Fellowship. Founded by the friends of Charles Allen Munn as a memorial to him. Available in this University for research in pure science. Stipend, $800 a year.

Munn (Orson Desaix) Fellowship in Electrical Engineering. Founded by Mr. Charles A. Munn, 1908. Available in this University for the study of electrical engineering. Applications should be filed by April 15th with the Chairman of the Department of Electrical Engineering.

Plaut (Albert) Fellowship in Chemistry. Founded by Edward Plaut in memory of his father. Available in this University for the study of chemistry. Stipend, $1000 a year.

Queen (James W.) Graduate Scholarship. Founded by Mrs. Abby S. Queen, 1908. Available in this University for the study of physics. Stipend, $400 a year.

Sayre Fellowship in Applied Chemistry. Founded by bequest of Dr. John Stanford Sayre, 1906. Open only to members of senior class of Princeton. Available in this University for the study of chemistry. Stipend, $800 a year.

Sayre Fellowship in Applied Electricity. Open only to the members of the senior class of Princeton. Available in this University for the study of electrical engineering.

Thaw Fellowship in Astronomy. Founded by Mrs. William Thaw, 1896. Available in this University for the study of astronomy. Stipend, $800 a year.

Walker (James Theodore) Fellowship in Psychology. Founded by bequest of James Theodore Walker, 1929. Stipend, $800 a year.

The following fellowships are not restricted to students in sciences; and there are other University fellowships which are likewise available for students in the sciences:

Green (Chancellor) Mental Science Fellowship. Originally founded in 1870 by the late Chancellor Henry W. Green, and permanently endowed in 1878 by his widow. Available to any member of the senior class who graduates from this University. Stipend, $800 a year. Applications should be filed by March 1st on special form furnished by the Dean of the Graduate School.

Procter (Charlotte Elizabeth) Fellowships. Ten. Founded by Mr. William Cooper Procter, 1912. Available in this University for study in any department. Stipend, $1400 a year.

Procter (Jane Eliza) Visiting Fellowships. Three. Founded by Mr. William Cooper Procter, 1921. Open to British and French scholars of British and French universities for resident advanced study and investigation in the Graduate College of this University. Applicants must be unmarried male citizens or subjects of the country from which they are recommended, and not over thirty years of age at the time of recommendation. Stipend, $2500 a year. Applications should be filed with the University of Oxford and the University of Cambridge in England, and École Normale Supèrieure in Paris.

PUERTO RICO, UNIVERSITY OF, SCHOOL OF TROPICAL MEDICINE, San Juan, Puerto Rico.

Ashford (Bailey K.) Fellowship. Established 1929, for the study of tropical medicine. Open to men and women qualified to do research work, preferably to those with an M. D. degree. Available only in this University. Stipend, $500 a year. Applications should be filed before March 30th.

PURDUE UNIVERSITY, Lafayette, Ind.

American Gas Association Fellowship. Established 1929 for work on a special problem. Open to men; granted upon recommendation of a special committee. Available only in Purdue University and to students of Purdue University. Stipend, $350 a year.

Assistantships. Open to men and women with a bachelor's degree. Stipend, $800 to $1000 a year; twelve hours per week required for teaching. Applications should be filed by June 1st with the President.

Babcock and Wilcox Fellowship. Established 1932, by the Babcock and Wilcox Company, for work on a special problem. Open to men with a B. S. degree plus practical experience. Stipend, $1150 a year. Available only in Purdue University.

Grigsby-Grunow Research (Purdue Research Foundation, Fellowship no. 23). Established 1929 by the Grigsby-Grunow Company, Chicago, to create new knowledge pertaining to the application of the cathode ray to television. Up to January 1, 1934, a total of $100,600 had been expended in connection with the project.

Lilly Fellowship in Immunology. Established 1933 by Eli Lilly Company. Stipend, $700. A special grant whose continuity is not guaranteed beyond the current year. Administered through the Purdue Research Foundation.

Lilly (J. K.) Fellowship. Established 1932, by J. K. Lilly, for research. Original amount, $3000. A special grant to the Purdue Research Foundation. The continuity is not guaranteed beyond the current year.

Lilly (J. K.) Fellowship no. 28 and no. 29. Established 1930, by J. K. Lilly, for research in pharmacy. Open to men and women with a baccalaureate degree in pharmacy, upon recommendation of former teachers. Stipend, $600 a year. Recipients of fellowships are permitted to go ahead with their graduate study unrestricted, except that their topic of research is selected for them. Applications should be filed by May 1st on special form furnished by C. B. Jordan, Dean of School of Pharmacy.

Mallinckrodt Chemical Works Fellowship. Established 1931, by Mallinckrodt Chemical Works for research on special problem. Open to men with a B. S. degree plus practical experience, for work in this University. Stipend, $800 a year.

National Millers Association Fellowship. Established 1929, by the Association, for research in wheat products. Open to men who are graduate students. Stipend, $1200 a year.

Research Fellowship no. 24. Established 1932, by the Phillips Petroleum Company, for special research. Original amount, $1600. A special grant whose continuity is not guaranteed beyond the current year. Administered by the Purdue Research Foundation.

RADCLIFFE COLLEGE, Cambridge, Mass.

Unless otherwise noted applications should be filed before March 1st with the Dean. Special application form furnished.

Bartol (Elizabeth H.) Fellowships. Three. Established 1928, by Miss Elizabeth Bartol. Unrestricted in subject. Open to women, sixteen to thirty-five years of age, for study at Radcliffe. Stipend, $400 to $600 a year.

Clementson (Henry) Scholarship. Founded by Mrs. Anne B. Clementson. Open to women, sixteen to thirty-five years of age. Available in this College for study of chemistry. Stipend, $300 to $600 a year.

Harvard Annex Scholarship. Founded by Radcliffe College alumnae. Open to women who are graduates of this College. Stipend, $300 to $600 a year.

Holden (Ruth) Fellowship. Open to American or English women students, for research in botany at Radcliffe College. Stipend, $210 to $300 a year.

Oliver-Dabney Scholarships. Founded by Mrs. Susan Heard Dabney for scholarships in belles-lettres, history or astronomy. Open to women, sixteen to thirty-five years of age, for study in this College. Stipend, $300 to $750 a year.

Pickering (Edward C.) Fellowship. Open to qualified students of Radcliffe College for graduate work in astronomy. For further information address Director of the Harvard College Observatory, Cambridge, Mass.

Radcliffe (Ann) Fellowship. Awarded without stipend to graduate students, resident or non-resident, on the same grounds of high scholarship and under the same conditions as to study and report as fellowships carrying incomes.

Strauss (Emily) Scholarship. Founded by Mrs. Emily R. M. Strauss. Open to women graduates, but ordinarily awarded to an undergraduate. Stipend, $300 to $500 a year.

Whitney (Augustus Anson) and Whitney (Benjamin White) Scholarships. Founded by Mrs. Abigail W. Howe. Open to women, sixteen to thirty-five years of age. Available at this College or abroad, for research. Stipend, $300 to $1500 a year.

RENSSELAER POLYTECHNIC INSTITUTE, Troy, N. Y.

Rensselaer Polytechnic Institute Fellowships. About ten; number of awards varies. Open to men who are graduates of scientific schools, including engineering schools, who are candidates for master's and doctor's degrees. Available at the Institute for one year for the master's degree, and for the doctor's degree, three years at the Institute, or two years with one year elsewhere. Stipend, $600 a year and free tuition. Applications should be filed by March 1st with the Director. Special application form furnished.

Sage Fellowships. Two. Founded by Mrs. Russell Sage, 1913. Open to men who are graduates of an engineering or other scientific school of the highest class. Available at the Institute for one year for the master's degree, and for the doctor's degree, three years at the Institute, or two years with the last year at any American university or abroad. Stipend,

$600 a year and free tuition. Applications should be filed by April 15th with the Director. Special application form furnished.

Scholarships. An undetermined number of scholarships carrying free tuition for students taking graduate courses leading to a master's degree.

RHODES SCHOLARSHIP TRUST, Office of the American Secretary, Swarthmore College, Swarthmore, Pa.

Rhodes Scholarships. Thirty-two for United States. Founded 1904. Open only to men. Minimum sophomore standing required, but eighty-five per cent of all scholars appointed have taken a bachelor's degree. Applicants must be between nineteen and twenty-five years of age, of high character and sound physique. Available in the University of Oxford, Oxford, England. Stipend, £400 a year. Applications should be filed by November 15th with Secretary of State Committee of Selection, whose name is printed on the back of the Memorandum furnished on request from the above address. The scholarship is given for two years but may be held for three years.

RICE INSTITUTE, Houston, Tex.

Carter (Samuel Fain) Fellowship. Founded 1932 by Mrs. Samuel Fain Carter. Open to men and women who are graduates from an approved institution of learning and who are of the white race, for advanced study. If a graduate of Rice Institute, the fellowship is available in another institution or abroad; if graduate of another institution, it is available at Rice Institute. Stipend, $900 to $1000 a year. Applications should be filed by January 1st with the Office of the President.

Rice Institute Fellowships. Fifteen. Open to men and women with a recognized degree, proper background for continuation of the studies desired and proper promise in research. Available in the following departments of the Institute: two in Physics Department, six in Chemistry Department, three in Biology Department and four in Mathematics Department. Stipend, $400 to $750 a year; duties of holders vary, but usually involve from six to nine hours per week of service in assisting in a laboratory or in the teaching of an elementary three-hour course. Applications should be filed by April 1st with Head of the department concerned.

Sharp (Walter B.) Memorial Fund for Research in Pure and Applied Science. Founded 1931, by Mrs. Walter B. Sharp. Available for scientific research, preference being given to geological research, the production of petroleum and the products closely allied thereto. Open to men with the Dh. D., degree for study in an American university or abroad. Stipend, $2000 to $2500. Applications should be filed by January 1st with the Office of the President.

RIPON COLLEGE, Ripon, Wis.

Graduate Scholarship. *See* Wisconsin, University of. Graduate Scholarships.

ROCHESTER, UNIVERSITY OF, Rochester, N. Y.

Columbia University Fellowship. Founded by Columbia University. Open to men and women, designated by the faculty of the University of Rochester for graduate study in the School of Mines, Engineering or Chemistry of Columbia University. Stipend, $350 a year.

Corn Industries Research Fellowship. Open to men with competence in biological chemistry and physiology. The subject of the research is: "The comparative influence of different sugars on the rate of glycogen formation and the rate of fat formation in the animal body"; "The effects of different sugars on the control of acidosis." Stipend, $3000. Applications should be sent in by June 1st. Renewal of grant not certain.

Research Fellowships in Sciences. Founded under terms of gift received from General Education Board. Open to men and women who have the equivalent of a master's degree, preferably more, and have established their ability to conduct researches. Available in this University. No definite stipend, largely dependent on training, qualifications, etc. No applications received.

ROCKEFELLER FOUNDATION, 49 West 49th St., New York, N. Y.

The Rockefeller Foundation grants fellowships in the fields of the medical sciences, the natural sciences, the social sciences, the humanities and public health. In addition, the Rockefeller Foundation and the General Education Board make grants for support of fellowships, under certain limitations, for citizens of the United States and Canada to the National Research Council, the Social Science Research Council and the American Council of Learned Societies. Fellowships are of three types:

1. Fellowships for general training, for persons preparing for special positions or completing professional training: generally given in connection with programs in which the Foundation is cooperating. Appointees designated as FELLOWS.
2. Fellowships for training in research, for persons who have finished their formal academic professional training and who show evidence of

becoming productive leaders in their fields. Appointees designated as RESEARCH FELLOWS.

3. Special fellowships, occasionally granted, for research, to mature men of established scientific reputation. Appointees designated as SPECIAL FELLOWS.

RUTGERS UNIVERSITY, New Brunswick, N. J.

Fellows are required to render some assistance in teaching or laboratory practice.

American Optical Company Fellowship. Founded 1932 for research and tests for the purpose of developing new processes and improving the qualities of optical glasses. Open to men who are graduates of a college of recognized standing with training in chemistry, physics and engineering—preferably ceramic engineering. Stipend, $1000. Applications should be filed with Prof. George H. Brown, Department of Ceramics, Rutgers University.

Blodgett Fellowship in Science. Founded by James H. Blodgett, Washington, D. C., 1906. Open to men who are graduates of Rutgers holding a B. S. degree. Available only in this University. Stipend, $200 a year and exemption from all fees. Appointment made once in several years for period of one year. Applications should be filed not later than May 1st with Registrar.

Bowker Chemical Company Research Fellowship. Founded 1933, by Bowker Chemical Company, to determine the value of copper compounds with particular reference to those compounds manufactured by the Company in the control of the foliage diseases of potatoes. Open to men who are graduates of a college of recognized standing, with training in biology, chemistry, physiology and plant pathology. Stipend, $500 a year. Applications should be filed with Dr. W. H. Martin, Department of Plant Pathology, Rutgers University.

Tile and Mantel Contractors Fellowships. Two. Founded 1931, by the Joint Board of Tile Manufacturers and Tile and Mantel Contractors Association, Trenton, N. J., for establishing the proper bonding formulas for all kinds of tile in relation to its installation and formulating standard practices. Open to men who are graduates of a college of recognized standing with training in chemistry and engineering—preferably ceramic engineering. Stipend, $2750 a year and $450 a year. Applications should be filed with Prof. George H. Brown, Department of Ceramics, Rutgers University.

Toxon Fellowship. Founded 1933 by the Toxon Company, Inc., to explore the field for the spray known as Toxon and to develop as a result of this work an agricultural spray that is superior to competitive products. Open to men who are graduates of a college of recognized standing, with training in biology, chemistry, physiology and entomology. Stipend, $2500 a year. Applications should be filed with Dr. T. J. Headlee, Department of Entomology, Rutgers University.

Vander Poel Fellowship in Chemistry. One or two. Founded by John A. Vander Poel, 1901. Open to men who are graduates or undergraduates of Rutgers. Available in this University for study of chemistry (preferred) or other science. Stipend, $1000 a year; twelve hours per week required in service. Applications should be filed not later than May 1st with the Registrar.

ST. LOUIS UNIVERSITY, 221 North Grand Blvd., St. Louis, Mo.

Graduate Fellowships and Scholarships. One hundred and twenty-five in 1933-34 (19 graduate fellowships in clinical sciences; 7 in medical social work; 57 graduate scholarships). Open to men and women with acceptable training, for study in the respective departments of the University. Basic stipend, $300 and freedom from tuition for nine months for Graduate Fellows. In general the stipend will vary with the qualifications and training of the appointee. It ranges in practice from $250 to $1000 and carries exemption from tuition fees. Applications should be filed by March 1st of the preceding year, on special form supplied by Graduate School, 15 North Grand Blvd., St. Louis, Mo.

Mead Johnson and Company Fellowships. Two. This Company makes an annual grant of $1500 in support of two fellowships in clinical sciences to which the University adds tuition fees and maintenance.

Parke, Davis and Company Fellowship. This Company makes an annual grant of $800 in support of one fellowship in endocrine research to which the University adds tuition fees.

ST. LUKE'S HOSPITAL, Chicago, Ill.

Blair (Watson K.) Memorial Fund. Founded 1929, by Watson F. Blair, for medical research. Open to technical assistants or graduates in medicine. Stipend, $1000 to $1250 a year.

Borland (John Jay) Fellowship in Clinical Medicine. Founded 1922 by Mrs. John Jay Borland, for study in clinical medicine and pathology. Open to research graduates in medicine. Stipend, $1200 to $2500 a year.

Kuppenheimer (A. B.) Fund. Fellowship open to technical assistants. Stipend, $300 to $500 a year.

Lilly (Eli) Fellowship. Open to candidates for the Ph. D. degree in chemistry of the University of Chicago. Stipend, $1200 a year.

Peck (Winfield) Memorial Fund. One fellowship open to technical assistants. Stipend, $1020 a year.

SMITH COLLEGE, Northampton, Mass.

Applications, except when otherwise noted, should be filed by March 1st with the Committee on Graduate Instruction, Smith College. Special application form furnished.

Alumnae Fellowships. Two. Founded by the Alumnae Association of Smith College, 1916 and 1930. Open only to members of the graduating class of Smith College. Available in any American university or abroad for graduate study. Stipend, $600 a year; when used at Smith College, the tuition is free.

Fellowships for Foreign Students. Established 1918. Open to women graduates of recognized universities or equivalent status. Available only at Smith College. Stipend, tuition, maintenance and $100 in cash (value of $800). Applications should be filed on special form by February 20th with Chairman, Committee on Exchange of Students with Foreign Countries, Smith College.

Hawes (Harriet Boyd) Scholarship. Founded by the Class of 1892 in 1922. Open to graduates of Smith College or women graduates of some other college of good standing. Available for graduate study in Smith College or in any American university or abroad, if holder is graduate of Smith. Stipend, income from fund of $5500; when used at Smith College, the tuition is free.

Smith College Tuition Scholarships. Four. Open to graduates of Smith College and to women graduates of other universities and colleges of good standing. Available in this College for graduate study. Stipend, tuition.

Smith Student's Aid Society Fellowship. Founded by the Society, 1912. Open to members of the graduating class of Smith College and alumnae of the two preceding classes. Available in any American university or abroad for graduate study. Stipend, $700 a year. Applications should be filed by January 1st with Miss Nora Mohler, 261 Crescent St., Northampton, Mass. Special application form furnished.

Trustee Fellowships. Six. Founded by the Trustees of Smith College, 1902. Open to graduates from this College or women graduates of other colleges of good standing, in rare cases. If holders are graduates of Smith College, the fellowships are available in any American university or abroad; if holders are graduates of other institutions, the fellowships are available only at Smith College. Stipend, when used at Smith College, tuition, maintenance and $100 in cash (total value of $800).

Wilder (Sarah Watkins) and Whipple (Sarah Wheaton) Fellowship for Graduate Study in Zoology. Founded by the Trustees of Smith College, 1931. Open to graduates of Smith College and to women graduates of other colleges of good standing for graduate study in zoology at Smith College, or to Smith graduates or teachers in the Zoology Department of Smith College for study in zoology in other institutions. Stipend about $500; when used at Smith College, tuition fees are remitted.

SMITHSONIAN INSTITUTION, Washington, D. C.

Bacon (Walter Rathbone) Scholarship in Zoology. Founded 1925, by Virginia Purdy Bacon, for the study of zoology. Open to men and women with physical and scientific requirements requisite for the project submitted. Incumbent shall not engage in work for remuneration or receive salary from other sources than the Institution or its branches during the period of occupancy of the scholarship. Available in countries other than the United States. Stipend, $3000 a year. When scholarship is open, a notice is usually printed in *Science,* giving details and date for filing application.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, 29 West 39th St., New York, N. Y.

Scholarship. Established 1929. Open to men who are naval architects or marine engineers. Available in recommended place of study. Stipend, $1000 a year.

SOCIAL SCIENCE RESEARCH COUNCIL, 230 Park Avenue, New York, N. Y.

Research Fellowships in the Social Sciences. About twenty. Founded 1925, by Laura Spelman Rockefeller Memorial. In 1929 taken over by Rockefeller Foundation. Available for study in economics; social, economic and political history; political science; social psychology, sociology; cultural anthropology; statistics; and social aspects of related disciplines. Open to men and women, citizens of the United States or Canada, not more than thirty-five years of age, who have the Ph. D. or its equivalent in research training and experience. Available for study in any American university or abroad. Stipend, $1800 to $2500 a year plus travel and allowances. Applications should be sent in on special form before December 1st, to the Fellowship Secretary.

SOCIETY OF THE SIGMA XI, Professor Edward Ellery, Secretary, Union College, Schenectady, N. Y.

Sigma Xi Fellowships. From five to ten. Founded by alumni members and associates of Sigma Xi, 1921. Open to men and women whose work and competency are determined by prominent investigators in the particular field. Available in any American university or abroad for research. Stipend, $100 to $1000 a year. Applications should be filed before May 1st with the Secretary. Special application form furnished.

SOUTH DAKOTA STATE COLLEGE, Brookings, S. D.

Graduate Assistantships. From time to time as conditions change and laboratory assistance is needed, particularly in the science and technological departments of the College, it is the policy of the College to employ graduate assistants for part-time teaching work (usually half time), the remaining part of their time to be spent in graduate study. Stipend $500 to $800 for half time. No applications are solicited for these positions, as the departments employ persons only as circumstances determine. Because of lack of college funds the number of these assistantships has been reduced to three during the current year.

SOUTH DAKOTA STATE SCHOOL OF MINES, Rapid City, S. D.

Fellowships in Engineering. Two. Founded 1925. Open to men who are graduates of the School of Mines, capable of carrying on research and able to give assistance in laboratory instruction. Stipend, $600 a year; one-half time required in service. Applications should be filed by May 1st with the President.

SOUTHERN METHODIST UNIVERSITY, Dallas, Tex.

Fellowship in Biology. Open to men and women with an A. B. degree and major in biology, who are candidates for the master's degree. Available in this University. Stipend, $600 a year; three hours per week required in service. Applications should be filed before March 1st with the Dean of the Graduate School, or the Professor of Biology. Special application form furnished.

Graduate Scholarships. Six. Established 1928 for general scientific study. Open to graduates of this University. Stipend, $239 a year.

Applications should be filed by March 1st with Dean of the Graduate School.

Jones (Jesse H.) Graduate Scholarships. Founded by Jesse H. Jones. Open to graduates of reputable colleges for study in this University. Stipend, $250 a year. Applications should be filed as above.

Methodist College Graduate Scholarship. Open to graduates of Methodist Class A colleges west of the Mississippi River. Stipend, $239 a year. Applications should be filed as above.

Trustee Graduate Scholarships. Six. Established 1928. Open to men and women with an A. B. degree. Stipend, $239 a year. Applications should be filed as above.

SQUIBB AND SONS, E. R., 745 Fifth Ave., New York, N. Y.

Fellowships for research in clinical medicine, chemistry or biology are offered for a period of not less than twelve months and may be renewed for a further period of twelve months. Open to individuals having the degree of M. D. in the case of clinical fellowships, or the equivalent of Ph. D. for fellowships in chemistry or biology. Applications for these fellowships may be made by any individual connected with a recognized institution provided with facilities for clinical research or studies in chemistry and biology as related to medicine. Such applications must have the approval of the head of the department in which the work is to be conducted, and the administrative head of the institution. Applications should be sent to the Department of Professional Service Relations.

STANFORD UNIVERSITY, Stanford University, Calif.

Buckel Fellowship. Founded by Dr. C. Annette Buckel, 1914. Open to men and women. Available for the study of backward and feebleminded children. Stipend, $500 a year. Applications should be sent to the Executive Head, Department of Psychology.

DuPont Fellowship in Chemistry. Established 1928, by E. I. duPont de Nemours and Company. Annually available, $750. Application should be made to the Executive Head of the Department of Chemistry.

Franklin (Edward Curtis) Fellowship in Chemistry. Established 1929, from the Edward Curtis Franklin Testimonial Fund, presented to the University by the students, associates and other friends of Professor Franklin upon his retirement. Open to any properly qualified candidate in the Department of Chemistry. Stipend, $500 a year. Application should be made to the Executive Head of the Department of Chemistry.

Fries (Florence Hecht) Scholarship in Medicine. Founded by Mrs. Dorothy Fries Lilienthal, 1925. Open to men and women graduates or advanced undergraduates. Available in this University for the study of medicine. Stipend, $300 a year. Applications should be filed by April 4th with Committee on Scholarship. Special application form furnished.

Harvard Club Scholarships. The Harvard Club of San Francisco offers two scholarships, of the annual value of approximately $400 each, to students desirous of pursuing undergraduate studies in Harvard College or postgraduate studies in Harvard University. Open only to students residing in the neighborhood of San Francisco. Applications should be made in writing not later than April 15th to Dr. Philip King Brown, 909 Hyde St., San Francisco, Calif.

Jacobs (Donald Porter) Research Fellowship. Founded 1928 by Mr. and Mrs. Albert P. Jacobs in memory of their son. Open to a worthy graduate student for whatever field of study may seem most desirable at the time. Principal, $5000. Annually available, approximately $200. Application should be made to the Committee on Graduate Study.

Jordan (Eric Knight) Research Fellowship in Geology. Founded 1926 by Dr. and Mrs. David Starr Jordan in memory of their son. Open to men and women, for research in this University. Annually available, approximately $500 a year. Application should be made to the Committee on Graduate Study by February 15th.

Newell (Henry) Scholarships. Founded 1932 under the will of Henry Newell. Awarded to men and women, graduate or undergraduate, preferably from the state of Utah, who have shown excellence in school or college work and are in need of financial aid to complete their courses of study. Income, $4200. Annually available, $300 to each one holding scholarship.

Physical Therapy Fellowship. Founded 1923 by anonymous donor, to be known as the Rehabilitation Fund of the Medical School. Provides a fellowship for six months, with stipend of $300 for that time. Application should be made to the Dean of the Stanford School of Medicine, San Francisco.

Rixford (Dr. Emmet) Scholarship Fund. Founded 1921 by Dr. Rixford, Professor of Surgery in the Stanford School of Medicine with a gift of $500 to be awarded annually to some graduate of the School or to some staff member of rank under that of assistant professor, to be chosen by the medical faculty, for work on some surgical problem—anatomical, physiological, pathological or clinical—the problem to be approved by the faculty. In 1928 the unexpended balance of the fund, amounting to $1000 was placed in a permanent fund to draw interest until such time as additional gifts will make the income sufficient for support of an annual scholarship or fellowship.

Ryan (Harris J.) High-voltage Laboratory Research Fellowship. Established 1926 by Dr. and Mrs. Harris J. Ryan, for research in the Electrical Engineering Department. Stipend, $500 a year. Application should be made to the Executive Head of the Department of Electrical Engineering.

Shell Research Fellowship. Established 1929 by the Shell Development Company, to be used for the advancement of learning in the field of physical or organic chemistry. Stipend, $900 a year. Application should be made to the Executive Head of the Department of Chemistry.

Stanford (Thomas Welton) Fellowship in Psychic Research. Founded as a fund in 1913 from which the Trustees have established this fellowship for research in psychic phenomena.

Stanford Student Chapter of the American Society of Civil Engineers Scholarhips. Founded by Stanford Chapter, 1925. Open to men and women who are graduates or advanced undergraduates. Available in this University for the study of civil engineering. Stipend, $300 a year. Applications should be filed by April 4th with the President of the Chapter, or the Civil Engineering Department. Special application form furnished.

Stillman (John Maxson) Scholarship in Chemistry. Founded by Stillman Testimonial Fund, 1917. Open to men and women who are graduates or undergraduates in chemistry, for study in this University. Stipend, $150 a year. Applications should be filed by April 4th with the Executive Head of the Department of Chemistry. Special application form furnished.

Teaching Fellowship in Mineralogy. Established 1930 by the Board of Trustees. Stipend, $750 a year. Application should be made to the Professor of Mineralogy.

University Fellowships. Established 1917, 1919 and 1925. Twelve. In general these fellowships will not be awarded to students in their first year of graduate study. Requests for reappointment to University Fellowships, as well as new applications, must be in the hands of the Committee on Graduate Study by February 15th preceding the academic year for which the fellowship is desired. Stipend, eight at $750 each per year of three quarters; four at $400 a year.

University Graduate Scholarships. Established 1919 and 1927. Thirty-six. Holders are required to pay tuition and community fees, graduation fee, laboratory expenses and all similar charges laid upon other graduate students. Stipend, thirty, each paying $200 per year of three quarters; six, $100 per quarter for four quarters. Application should be filed by April 4th with Committee on Scholarship. Special application form furnished.

Victor (Royall) Fellowships. Established 1927, under the will of Charles F. Brooker, in memory of Royall Charles Victor of the class of 1900. Preference is given to candidates, if any, of the requisite qualifications who reside or have resided in the state of Connecticut. Principal, $117,054. Annually available, $5500.

Willard (Charles W.) Scholarship. Founded 1925 by the partners and family of Charles W. Willard. Open only to graduates of the Stanford School of Nursing, who, in the opinion of the Superintendent of the Hospital and the Superintendent of Nurses, are best qualified to pursue such advanced course of study as that in administrative, public health or social service work. Principal, $5000. Annually available, $250.

Windt (Henry, Jr.) Memorial Scholarship in Engineering Chemistry. Founded 1927 by gift of Henry and Viola Windt in memory of their son. Principal, $8500. Annually available, $325. Applications should be filed by April 4th with Committee on Scholarship. Special application form furnished.

STEWARDSON (JOHN) MEMORIAL SCHOLARSHIP IN ARCHITECTURE, W. Pope Barney, Secretary, 1805 Walnut St., Philadelphia, Pa.

Stewardson (John) Memorial Scholarship in Architecture. Available to pursue the study of architecture in this or foreign countries as determined by the Managing Committee. Open to persons who shall have studied or practised architecture in the State of Pennsylvania for the period of at least one year immediately preceding the award. The age limit is from twenty-two to thirty years. Candidates must have completed at least three years of office experience, or two years of office experience and one year in an approved school of architecture, or one year of office experience and two years in an approved school of architecture. Stipend, $1000 a year. Applications should be filed not later than March 15th with the Secretary. The competition is restricted to five competitors chosen by the Managing Committee from the applicants.

SWARTHMORE COLLEGE, Swarthmore, Pa.

Leedom (Hannah A.) Fellowship. Founded 1913, by Hannah A. Leedom, for general scientific study. Open to men and women who are graduates from Swarthmore College, who have published or unpublished papers as evidence of ability for advanced study. Available in any American university or abroad. Stipend, $500 a year. Application should be made on special form furnished by March 1st and sent to Chairman of Committee on Fellowships.

Lippincott (Joshua) Fellowship. Founded 1893, by Howard W. Lippincott, in memory of his father. Open to men and women, graduates of Swarthmore College, who have published or unpublished papers as evidence of ability for advanced study. Available in any American university or for study abroad. Stipend, $600 a year. Applications should be filed by March 1st on special form furnished by the Chairman of Committee on Fellowships.

Lockwood (John) Memorial Fellowship. Founded 1910, by Lydia A. Lockwood, in memory of her brother, Joshua Lockwood. Open to men and women, graduates from Swarthmore College, who have published or unpublished papers as evidence of ability for advanced study. It was the wish of the donor that the fellowship be awarded to a member of the Society of Friends. Stipend, $600 a year. Available in any American university or for study abroad. Applications should be filed by March 1st on special form furnished by the Chairman of the Committee on Fellowships.

Mott (Lucretia) Fellowship. Founded 1895, by life members of the Somerville Literary Society. Open to women of the graduating class of Swarthmore College, in high standing from the beginning of the Sophomore year. Thesis or other evidence of ability for advanced study is required. Stipend, $525 a year. Available for general scientific study in any American university or abroad. Applications should be filed with Dean of Women, Swarthmore College.

Sigma Xi Research Fellowship. Founded 1933, by Swarthmore Chapter of the Society of Sigma Xi. Open to men and women (in general) associates of the chapter, who are graduates from Swarthmore College and have done advanced graduate work of outstanding quality. Stipend, $1000 a year. Available in any American university or for study abroad. Applications should be filed by February 15th, on special form furnished, with the Secretary, Swarthmore Chapter, The Society of Sigma Xi, Swarthmore College.

Tyson (Martha E.) Fellowship. One biennially. Founded 1913, by life members of the Somerville Literary Society. Open to women who are graduates from Swarthmore College in high standing, who have had success in teaching for two years after graduation and who intend to continue teaching. Stipend, $500 or more. Available for study in any American university or abroad. The Fellowship will not be awarded for 1934-35. Applications for 1935-36 must be received by the Committee of Award not later than February 15, 1935. Special application form furnished by Dean of Women, Swarthmore College.

SYRACUSE UNIVERSITY, Syracuse, N. Y.

Graduate Assistantships. Fifteen to twenty in science and technology. Open to men and women with a bachelor's degree, high to superior rating, generally under twenty-five years of age, with thirty years as a limit and a promise in research and aptitude in teaching in elementary laboratory sections. Available in the specific fields covered by the departments. Stipend, $500 to $750 a year; in general one-half time is given to teaching. Applications should be filed by March 15th with Dean of the Graduate School.

Graduate Fellowships. Ten. Founded 1916. Open to men and women with a bachelor's degree, with high rank, generally under twenty-five years of age and with thirty years as a limit. Available in the specific departments in which applicants desire to study. Stipend, $500 a year and exemption from tuition and laboratory fees. Applications should be filed by March 15th with the Dean of the Graduate School. None available for 1934-35.

Resident Dormitory Awards. Twenty. Established 1930. Emphasis not on research but channels are open. Open to women with a baccalaureate degree plus experience in teaching, personnel work or research, from twenty-three to thirty years of age. Stipend, $700 to $800 in terms of room and board.

TENNESSEE, UNIVERSITY OF, Knoxville, Tenn.

Teaching Fellowships. Nine. Established 1922 for the study of chemistry (4), botany (1), bacteriology (1), entomology (1) and zoology (2). Open to men and women with B. S. degree with major training in the field offering the fellowship. Available only in this University. Stipend, $400 a year. Applications should be filed approximately by April 15th on special form furnished, with the Head of the department concerned. The number of fellowships and the stipends have been reduced the last two years. Duties consist of a maximum of 12 hours teaching in class rooms and laboratories.

TEXAS, AGRICULTURAL AND MECHANICAL COLLEGE OF, College Station, Texas.

Cotton Seed Oil Mill Fellowships. Three. Texas Cotton Seed Crushers Association (two); Anderson, Clayton Co. (one). Open to men with an A. B. or B. S. degree from a recognized institution, with major in chemistry. Available in this University for research in cotton seed oil mill problems. Stipend, $405 a year. Applications should be filed by April 1st with Professor of Chemistry.

Graduate Assistantships. Fifty. Open to men with an A. B. or B. S. degree with major in field in which graduate work is to be done. Available in this University. Stipend, $405 a year; approximately half-time service required. Applications should be filed by April 1st with the Dean of the Graduate School. Special application form furnished.

Graduate Fellowships. Seven. Founded 1924. Open to men with an A. B. or B. S. degree with major in the field in which the graduate work is to be done. Available in this University. Stipend, $405 a year; approximately half-time service required. Applications should be filed by April 1st with the Dean of the Graduate School. Special application form furnished.

TEXAS CHRISTIAN UNIVERSITY, Fort Worth, Texas.

Fellowships. Six. Founded by the Burnett Fund, 1924. Open to men and women with a bachelor's degree and thirty semester hours in the chosen subject. Available in this University. Stipend, $250 to $300 a year; three to six hours per week required in service. There is one fellowship in biology, one in geology, two in chemistry and two in physics. Applications should be filed by March 1st with the Head of the department concerned.

TEXTILE FOUNDATION, THE, Commerce Bldg., Washington, D. C.

The Textile Foundation. Established June 11, 1930, by Act of Congress, to administer and expend its funds and other property for scientific and economic research for the benefit and development of the textile industry, its allied branches, and including that of production of raw materials. Original amount, $1,200,000, which will be supplemented by $200,000 or $300,000 still to be paid in from the original source (The Textile Alliance, Inc.). Approximately $30,000 a year is expended for the support of fellowships. There are Scholars, and Junior and Senior Fellows. The Senior Fellows are required to have a doctor's degree or the equivalent in work. All are assigned to university laboratories, with no limit on place of study. Stipend, for Scholars, $750 a year; for Junior Fellows, unmarried $1000, married, $1200 a year; for Senior Fellows, unmarried, 1st appointment $2000; reappointment, $2200; married, 1st appointment, $2400, reappointment, $2700. The awards are open to both men and women. It is the present plan not to receive applications except on invitation when and if vacancies become available.

TRINITY COLLEGE, Hartford, Conn.

Graduate Scholarships. There are a number of graduate scholarships covering tuition and room rent for graduate students at Trinity College. It is not necessary that applicants be graduate of this College.

Russell Fellowship. Awarded biennially. Founded by Henry E. Russell, 1893. Open to men in the graduating class of Trinity College. Available in any American or foreign university approved by the Faculty. Stipend, $500 a year. Applications should be filed by May 1st with the Secretary of the Faculty.

Russell (W. H.) Fellowship. Awarded biennially. Founded by William H. Russell, 1927. Open to men who are members of the graduating class of Trinity College. Available in any American or foreign university approved by the Faculty. Stipend, $500 a year. Applications should be filed by May 1st with the Secretary of the Faculty.

Terry Fellowship. Founded by Miss Mary A. Terry, 1904. Open to men who are members of the graduating class of Trinity College. Available in any American or foreign university approved by the Faculty. Stipend, $600 a year. Applications should be filed by May 1st with the Secretary of the Faculty.

TRUDEAU FOUNDATION, EDWARD L., Saranac Lake, N. Y.

Trudeau Foundation Fellowships. Six annually. Founded by numerous donors, 1916. Restricted to research in tuberculosis at the Trudeau Sanatorium. Open to men and women, Class A medical students and graduates under fifty who have had tuberculosis which has been arrested. Stipend, $840 to $1000 a year. Application should be filed before March 1st and October 1st. Special application form furnished by Dr. Edward R. Baldwin, Director.

Trudeau School of Tuberculosis Scholarships. Five. Founded by numerous donors, 1916. Open to men and women, medical students and recent graduates, generally under fifty. Preference is given to tuberculous physicians after recovery. Available in the Sanatorium for a six weeks course in tuberculosis. Stipend, tuition. Applications should be filed before March 1st with the Secretary, Trudeau School. Special application form furnished.

TUFTS COLLEGE, Tufts College, Mass.

Scholarships. Six. Founded 1893. Open to men and women, twenty-one years of age or over, with a bachelor's degree. Available in this College for study in biology, chemistry, mathematics, engineering, physics and economics. Stipend, $300 a year. Applications should be filed by October 1st with the Dean of the Graduate School.

TULANE UNIVERSITY OF LOUISIANA, New Orleans, La.

Alumni Teaching Fellowship. Founded 1921. Open to men who are graduates of Tulane. Available in this University. Stipend, $250 a year and free tuition; three to five hours per week required in service. Applications should be filed with the President of the University.

Fellowships in Newcomb College (the Women's Department) awarded by the Board of Administrators to graduates of Tulane University or of other institutions of equal rank who are found, after careful examination, to be especially fitted by reason of scholarship, maturity and character to give instruction under the direction and supervision of professors in charge. In each instance the fellow is expected to do graduate work, selecting her major subject in the department in which she gives instruction. The holders of these fellowships receive $250 a year with free tuition. Information regarding these fellowships may be obtained from the Dean of Newcomb College.

Teaching Scholarships. Founded 1912. Open to men and women who are teachers of attainment on actual leave of absence for the purpose of further study, who can furnish satisfactory evidence of ability. Stipend, tuition. Applications should be filed with the President of the University.

U. S. BUREAU OF MINES, Washington, D. C.

The following six educational institutions finance fellowships which are carried out in the laboratories of the Bureau of Mines under the direction of government technologists: Missouri School of Mines and Metallurgy; University of Utah; University of Alabama; University of Arizona; University of Nevada; University of Washington. Arrangements are made through the universities and not through the Bureau. For further details see the individual institutions named.

UNIVERSITY OF THE SOUTH, Sewanee, Tenn.

Columbus, Ga., Graduate Scholarship. Founded by George Foster Peabody. Open to men with an A. B. or B. S. from this University. Available in any American university or abroad. Stipend, up to $300 a year. Applications should be filed three months before graduation, with the Dean of the College.

UTAH, UNIVERSITY OF, Salt Lake City, Utah.

Metallurgical Research Fellowships. Five. Awarded to graduates, preferably of mining schools, who have shown special aptitude for research investigations in metallurgy, and are candidates for the master's degree. Class work is directed by the Heads of the departments of instruction, but laboratory work is under the supervision of the metallurgists of the U. S. Bureau of Mines, assigned to duty at the University. Stipend, tuition.

Park (John R.) Teachers' Fellowships. Established 1900 by John R. Park for the faculty members of the University of Utah. Open to men and women. Available for study in any American university or abroad. Stipend, $400 to $600 a year. Applications should be filed not later than February 1st with the President, University of Utah.

VANDERBILT UNIVERSITY, Nashville, Tenn.

Eagen Fellowship in Chemistry. Founded 1931 by the American Cast Iron Pipe Company, for the study of metallurgy. Open to men with an A. B. or B. S. degree. Available only in this University. Stipend, $800 a year. Applications should be filed before March 1st on special form furnished by the Department of Graduate Instruction.

Graduate Scholarships. Twenty. Established by the Board of Trust. Open to graduates of standard colleges who will presumably be able to qualify in one year for the master's degree. The holder gives a limited amount of assigned service to the University, otherwise he is expected to devote his full time to graduate study and to have no outside occupation. Stipend, $300 a year. Applications should be addressed to the Secretary of the Committee.

Teaching Fellowships. Open to graduates with the bachelor's degree who are recommended for appointment by the department interested. The teaching fellow is expected to pursue his graduate studies and to be a teaching assistant under the direction of some department. He pays fees at regular rates but is exempt from the laboratory fees charged in the science courses. Stipend, $500 a year. Teaching Fellowships are now available in the Departments of Biology, Chemistry, Economics, English, Geology, German, History, Mathematics, Physics and Sociology. Application should be addresesd to the department.

VASSAR COLLEGE, Poughkeepsie, N. Y.

Applications should be filed by February 15th with the President, unless otherwise noted. Special application form furnished.

Babbott (Mary Richardson and Lydia Pratt) Fellowship. Founded by Mrs. Frank L. Babbott, 1894 and increased in 1919 by members of donor's family. Open to all graduates of Vassar College and to members of the faculty holding a Bachelor of Arts degree. Available in any American university or abroad. Stipend, $600 a year.

Clark (Nancy Skinner) Fellowship. Founded by Mr. William Skinner, 1928. Open to women who have an A. B. from Vassar College. Preference is given to members of the graduating class. Available in any American university or abroad for the study of botany. Stipend, $800 a year.

Fellowship of Associate Alumnae of Vassar College. Open to graduates of Vassar with an A. B. degree. For 1930-31 and each third year thereafter, the fellowship is open to instructors and assistant professors on Vassar faculty on the same terms as to the alumnae. Available in any American university or abroad. Stipend, $1000 a year. Applications should be filed by February 1st with Committee on Graduate Work and Publication, Alumnae Office, Vassar College.

Graduate Fellowships. Four. Open to women who have an A. B. degree from Vassar. Available in any American university or abroad. Stipend, $800 a year.

Kendrick (James Ryland and Georgia A.) Fellowship. Founded by Miss Myra H. Avery, 1923. Open to women who have an A. B. from Vassar College. Only members of current senior class, or alumnae of one year's standing are eligible. Available in any American university or abroad.

Nourse (Mary Pemberton) Fund Fellowship. Founded by a group of alumnae, 1922. Open to women for the study of public health. Stipend, $1500 a year. Full information may be obtained from the American Association of University Women, Washington, D. C.

Sutro Fellowship. Founded by Adolph Sutro, 1913. Open to women who have an A. B. degree from Vassar College, and are graduates of not more than five years standing. Available in any American university or abroad. Stipend, $1000 a year.

Van Loon (Louise Hart) Fellowship. Founded by Vassar Students' Aid Society, 1904, and increased in various years thereafter. Open to women who have an A. B. from Vassar College. Available in any American university or aboard. Stipend, $600 a year.

VERMONT, UNIVERSITY OF, Burlington, Vt.

Applications should be filed before July 1st with the Chairman of the Committee on Degrees.

Research Fellowships. Several. Open to students whose undergraduate record and personal qualities give promise of success either in research or in the profession of teaching. Holders are expected to devote their time to the study of some special problem of research, and may be called upon to assist in the work of the department to which they are assigned. They must study for some advanced degree, usually that of M. A. or M. S. Stipend, $700 the first year and $800 the second year, with exemption from tuition.

Research Scholarships. Ten. Open to graduates of colleges and universities of recognized standing. Stipend, tuition.

VIRGINIA POLYTECHNIC INSTITUTE, Blacksburg, Va.

Fuel Engineering Research Fellowships. Six fellowships for research in fuel engineering. Open to men with a B. S. degree in mechanical or electrical engineering and a satisfactory undergraduate record. Available in this College. Stipend, $600 a year and fees; twenty-five clock hours per week required in service, which is credited toward a degree. Applications should be filed by April 15th with Committee on Graduate Programs and Degrees.

Teaching and Research Fellowships. Nine for teaching; six for research. Open to men and women with a B. S. degree and a satisfactory undergraduate record. Available in this College. Stipend, $300 to $600 a year and fees; ten to twenty clock hours per week required in service, usually of such a type as to be credited wholly or partially toward a degree. Applications should be filed by April 15th with Committee on Graduate Programs and Degrees.

VIRGINIA, UNIVERSITY OF, Charlottesville, Va.

Bayly-Tiffany Fellowships. Six to eight. Established 1930 by a bequest of Mrs. Evelyn May Bayly-Tiffany as a memorial to Thomas Henry Bayly and Evelyn and Louis McLean Tiffany. Preference will be given, where practicable, to students from Northampton and Accomac Counties, Va. Stipends range from $200 to $500 a year.

Blandy Fellowships. Five. Open to men and women with a bachelor's degree from a college or university of recognized standing, who have had special training in biological and agricultural subjects, for research in genetics at Blandy Experiment Farm. Stipend, $500 to $1000 a year and free tuition. Applications should be filed by March 15th on special form furnished by the Director of the Blandy Farm, University, Va.

College Fellowships. One for each of a list of colleges selected by the faculty. Stipend, for Virginians, the remission of the University fee, $50; for non-Virginians, the remission of the tuition fee, $90. The holder must be a graduate of one of the designated colleges and must enter the University the session following his graduation. Appointments are made upon the recommendation of these colleges.

duPont Junior Fellowships. Twelve. Established 1928, by Philip Francis duPont. Open to men and women, not over 37 years of age, who hold the bachelor's degree. Available in this University for study in scientific and humanistic subjects. Stipend, $200 for Virginians; $250 for non-Virginians. Applications should be filed by March 15th on special form furnished by the Secretary, Graduate Department.

duPont Research Fellowships. Twelve. Established 1928, by Philip Francis duPont. Open to men and women, advanced graduate students, who are candidates for Ph.D. degree who must devote their time to research under the direction of the department concerned. There is an age limit of 37 years. Available in this University for study in scientific and humanistic subjects. Stipend, $500 to $750 a year. Applications should be filed by March 15th on special form furnished by the Secretary, Graduate Department.

duPont Senior Fellowships. Fifteen. Founded 1928 by Philip Francis duPont. Open to students, men and women, who have had at least one full year of graduate study and who have accomplished work equivalent to that required for the master's degree. There is an age limit of 37 years. Available in this University for study in scientific and humanistic subjects. Stipend, $350 a year. Applications should be filed by March 15th on special form furnished by the Secretary, Graduate Department.

Garrett (Elizabeth B.) Fellowship. Founded 1918, by Mrs. Elizabeth B. White. Open to men and women, graduate students. Appointments are made upon the recommendation of the Dean of the Department of Graduate Studies. Stipend, $260 to $280 a year. Available in the University of Virginia. Applications should be filed by March 15th on special form furnished by the Secretary, Graduate Department.

Green (Bennett Wood) Fellowships. Two. Founded 1914, by Dr. Bennett Wood Green. Open to men only. In making appointments, preference will be given to Doctors of Medicine of this University who are also masters of arts of the University; masters of arts of this University; bachelors of laws of the University who are also masters of arts of the University; and in all cases to native Virginians, and then to native residents of other Southern states. Available either in American or foreign universities. Stipend, $600 a year. Applications should be filed by March 15th on special form furnished by the Secretary, Graduate Department.

MacDonald (Captain Craig Woodrow) Memorial Fellowship. Founded 1930, by a bequest of his sister, Susan L. Stanard, of Charles Town, W. Va. Preference will be shown near or blood relative of the founder. Stipend, $225 a year. Applications should be filed by March 15th with the Dean of the Department of Graduate Studies.

Mason (John Y.) Fellowship. Founded 1892, by Col. Archer Anderson. The holder must be a competent and deserving graduate student, who was born in Virginia, in need of such assistance. Available only in this University. Stipend, $325 to $350 a year. Applications should be filed by March 15th on special form furnished by the Secretary, Graduate Department.

Merck Fellowship in Alkaloid Chemistry. Established by Merck and Co. to stimulate and encourage work in alkaloid chemistry, and to be awarded to a student of marked calibre, the selection being made by Dr. Lyndon F. Small, of the Research Staff in Chemistry, from whom additional information may be obtained. Stipend, $700 per year.

Service Fellowships. Fellowships entailing a certain amount of teaching or other assistance, administered from the Office of the President of the University. There are five in biology, founded in 1929, with an income of $250 to $750 each; several in chemistry, founded in 1919, with an income of $450 each, and exemption from tuition; seven in physics, with incomes varying from $200 to $500 each. The holder must have a baccalaureate degree.

Vanderbilt Fellowships in Astronomy. Three. Founded 1896. The holder must be a graduate student taking astronomy and must occupy a portion of his time in work connected with the Observatory. Stipend, $350 a year. Applications should be filed by March 15th with the Director of the Leander McCormick Observatory, University of Virginia.

WASHINGTON, STATE COLLEGE OF, Pullman, Wash.

Applications should be filed by April 1st with the Graduate School, unless otherwise noted. Special application form furnished.

Experiment Station Research Fellowship in Chemistry. Founded 1928. Open to men who have a bachelor of science degree in chemistry. Available in this Institution for research in biochemistry. Stipend, $510 for eleven months; approximately half time required in service.

Experiment Station Research Fellowship in Farm Crops. Two. Founded 1928. Open to men who have a bachelor of science in agriculture. Available in this Institution. Stipend, one at $600 for eleven months, and one at $680; approximately half time required in service.

Galland Graduate Fellowship. One or two. Founded by Julius Galland. Available to a Jewish student, who is a graduate from a college or university, of superior scholarship and ability, for general scientific study at the State College of Washington. Stipend, $350 a year. Applications should be filed by May 1st with Dr. E. C. Colpitts, Chairman, Galland Scholarship Committee, State College of Washington.

Letterman-Lanning (Emma M.) Fellowship. Founded by Mrs. Ella Letterman-Lanning. Open to men who are graduates from accredited colleges or universities for general scientific study in this College. Stipend, about $150 a year.

McCroskey (R. C.) Research Fellowship. Founded 1922. Open to men and women with bachelor's degree. Available in this Institution. Stipend, $300 to $400 a year. Applications should be filed by March 15th with the President's Office.

Research Fellowship in Plant Pathology. Founded 1928. Open to men with a bachelor of science degree in agriculture. Available in this Institution. Stipend, $510 for eleven months; approximately half time required in service.

Research Fellowship in Poultry Husbandry. Founded 1928. Open to men with a bachelor of science degree in agriculture. Available in this Institution. Stipend, $510 for eleven months; approximately half time required in service.

Research Fellowship in Soil Bacteriology. Founded 1928. Open to men with a bachelor or master of science degree in agriculture or bacteriology. Available in this Institution. Stipend, $500 for the school year; approximately half time required in service.

State Experiment Station Research Fellowship in Farm Management. Founded 1921. Open to men with a bachelor's degree in agriculture. Available in this Institution. Stipend, $510 a year; not less than half time required in service.

State Experiment Station Research Fellowship in Plant Pathology. Two. Open to men with a master's degree in plant pathology or in botany. Available in this Institution. Stipend, $510 each, a year; not less than one-half time required in service.

State Experiment Station Research Fellowship in Soils. Founded 1928. Open to men with a bachelor's or master's degree in agriculture. Available in this Institution for the study of problems in plant nutrition or other phases of soil fertility. Stipend, $500 a year; half time required in service. Applications should be filed by March 1st.

Teaching Fellowship in Civil Engineering. Founded 1928. Open to men with a bachelor of science degree in civil engineering. Available in this University. Stipend, $700 per school year; approximately one-half time required in service.

Teaching Fellowship in Dairy Husbandry. Founded 1928. Open to men with a bachelor of science degree in agriculture. Available in this University. Stipend, $800 a year; approximately half time required in service.

Teaching Fellowship in Electrical Engineering. Founded 1928. Open to men with a bachelor of science degree in electrical engineering. Available in this University. Stipend, $700 per school year; approximately half time required in service.

Teaching Fellowship in Mechanical Engineering. Founded 1926. Open to men and women who are engineering graduates. Available in this University. Stipend, $1000 to $1100 a year; twenty hours per week required in service. Applications should be filed by March 1st.

WASHINGTON, UNIVERSITY OF, Seattle, Wash.

Applications should be filed by March 1st with Dean of the Graduate School, unless otherwise noted. Special application form furnished.

Anderson (Agnes Healy) Research Fellowships. Established 1929 to provide fellowships in forestry. Two fellowships are offered in the amount of $420 a year each, and one fellowship in the amount of $550.

Bon Marche Industrial Fellowship. Founded by the Bon Marche of Seattle, 1920. Open to women who are graduate students in home economics. Available in this University for research in textiles. Recipient is required to give one-fourth of her time for eleven months to testing of textiles for the Bon Marche. Stipend, $500 a year.

Denny (Loretta) Fellowships. Three. Founded 1907. Open to graduate students in any department of the University. Awarded by the Faculty on the basis of scholastic excellence and general merit, but only to those who need financial assistance. Stipend, $500 a year.

MacKay (William) Scholarship. Established 1929. Open to students in the Department of Mining Engineering. Two scholarships available with an annual stipend of $125.

U. S. Bureau of Mines Fellowships. Four. Offered by the College of Mines in cooperation with U. S. Bureau of Mines. Open to graduates of universities and technical colleges who are properly qualified to undertake research investigations. Available for research in coal, metallurgy and clay. Holders register as graduate students and become candidates for the M. S. degree, unless an equivalent degree has previously been earned. Stipend, $725 for the twelve months beginning July 1st.

University Graduate Scholarships. Open to men and women who are graduates in the fields of botany, forestry and psychology. Available in this University. Stipend, $162 a year; twelve hours per week are required in service. Applications should be filed by March 1st with Chairman of the department concerned.

University Teaching Fellowships. Open to men and women who are graduates in the fields concerned. Available for study in physics and chemistry, with a stipend of $648 a year; in bacteriology, botany, mathematics, pharmacy, psychology and zoology with a stipend of $540 a year. Twenty-two hours per week are required in service.

WASHINGTON UNIVERSITY, St. Louis, Mo.

American Creosoting Company Fellowship in Botany. For timber research. For 1933-34, the stipend is $1200.

Barr (Jessie R.) Fellowships. Six. Founded by Mrs. Jessie R. Barr. Open to women, usually those who are second or third year graduate students. Available in this University and may be used in science or technology. Stipend, approximately $400 a year. Applications should be filed by March 15th with Secretary of the Board of Graduate Studies. Special application form furnished.

Graduate Assistantships. Several assistantships in the scientific departments are open to men or women with a bachelor's degree and major in subject of assistantship. Stipend, $500 to $750 a year; approximately one-half time required in teaching or laboratory work. Applications should be filed by February with the Professor in charge of the designated department. In the case of botany, address Professor G. T. Moore, Missouri, Botanical Garden, St. Louis.

Lilly (Eli) and Company Fellowship. For research in pediatrics. Stipend, 1933-34, $1200.

McMillan (Eliza) Graduate Scholarship. Open to women and may be used in science or technology. Stipend, approximately $250.

Mallinckrodt (Edward, Jr.) Fellowships. Two. For research in physics. Stipend 1933-34, $250 each.

National Research Council Fellowship. For research in radiation in zoology. Stipend 1933-34, $1200.

Steedman (James Harrison) Traveling Fellowship in Architecture. Available abroad for travel and study. Stipend, annual income on $30,000.

Surgical Fellowship. Founded 1916. Open to men and women who are graduates of medicine and have at least one year's hospital service, part of which has been surgical. Preference given to those who desire to specialize in neurosurgery. Available in the Washington University School of Medicine. Stipend, $100 a month. Applications should be filed before March 15th with Professor of Neurosurgery, Washington University School of Medicine.

University Fellowships and Scholarships. The University has appropriated for 1933-34 the sum of $7500 for fellowships and scholarships for graduate students of outstanding merit. These are general and may be used in science or technology. Stipend for these fellowships, $500 a year; scholarships, $200 a year.

Van Blarcom Scholarships. Several scholarships carrying tuition only are open to men or women and may be used in science or technology.

WELLESLEY COLLEGE, Wellesley, Mass.

Fellowships for Study of Orthopedics. Founded 1922. Open to women with a bachelor's degree; knowledge of chemistry, physics, biology, anatomy, kinesiology, physiology, elementary orthopedic theory and practice necessary. Available in this College. Stipend, $1000 a year. Applications should be filed before March 1st with the Director of the Department of Hygiene and Physical Education.

Graduate Scholarships. Eighteen. Open to women with a bachelor's degree. Available in this College. Stipend, tuition. Applications should be filed by March 1st with the Dean of Graduate Students.

Horton-Hallowell Fellowship. Founded by Alumnae Association of Wellesley College, 1923. Open to women with degree from Wellesley. Fellowship must be used for study leading to the Ph. D. degree, or in the pursuit of independent research of equivalent standard. Available in any American university or abroad. Stipend, $1250 a year. Applications should be filed by February 15th with Chairman of Committee on Alumnae Fellowship. Special application form furnished.

Palmer (Alice Freeman) Fellowship. Founded by Mrs. David P. Kimball, 1903. Open to women who are graduates of American colleges of approved standing, who have completed at least one year of graduate work and are not more than twenty-six at the time of appointment. Holder must remain unmarried throughout the tenure of the fellowship. Available in any American university or abroad. Stipend, about $1400 a year. Applications should be filed by February 1st with the Secretary to the President. Special application form furnished.

Workman (Fannie Bullock) Scholarship. Founded by bequest of Fannie Bullock Workman, 1929. Open to alumnae of Wellesley College. Available in any American university or abroad. Stipend, $1200 a year. Applications should be filed by February 1st with the Secretary to the President. Special application form furnished.

WESLEYAN UNIVERSITY, Middletown, Conn.

Cady (Kathrin Miller) Scholarship. Founded by Mrs. Caroline L. Miller, 1916. Open to men. Available in this University for the study of physics. Stipend, $180 a year.

Denison (C. H.) Research Fund. Established 1928, by Charles Land Denison, for biological research. Capital, $75,000. Annually available, about $3500. Income used to assist two or more graduates.

Graduate Research Assistants. Special provision is sometimes made in the budget for the appointment of graduate research assistants who do part time work. In 1933-34 one was appointed in physics, one in chemistry, one in astronomy and one in psychology.

WEST VIRGINIA UNIVERSITY, Morgantown, W. Va.

American Gas Association Fellowship. Established 1931, by the Natural Gas Department of the American Gas Association, for the study of natural gas problems. Open to men with a bachelor's degree. Available only in this University. Stipend, $500 a year. Application should be filed by June 1st with the Secretary of the Graduate Council. Special form furnished on request.

WESTERN RESERVE UNIVERSITY, Cleveland, Ohio.

Cushman Fellowship in Chemistry. Founded 1926. Open to men and women with an M. A. degree for study of chemistry in this University. Stipend, $900 to $1500 a year. Applications should be filed by March 1st on special form with Graduate School.

Ferro Enamel Corporation Fellowship, for research in chemistry. Stipend, $900 a year.

Westinghouse Fellowship. Founded 1932 by Westinghouse Electric and Manufacturing Company. Open to men and women with an M. A. degree for the study of chemistry in this University. Stipend, $900 to $1200 a year. Applications should be filed by March 1st on special form with Graduate School.

WILLIAMS COLLEGE, Williamston, Mass.

Clark (Horace F.) Prize Scholarships. Two. Founded by Mme. Marie Louise Souberbeille, 1894. Open to seniors of the College with superior scholarship, general ability and interest in scholarly research. Available in any American university or abroad for non-professional study. Stipend, $500 a year. In exceptional cases, the scholarship may be awarded as a single prize of $1000, or may be continued to the same holder for more than one year. Applications should be filed by May 15th with the Chairman, Committee on Prizes.

WISCONSIN, UNIVERSITY OF, Madison, Wis.

Application forms for any of the following appointments may be secured from the chairman of the department concerned or at the Graduate Office, Bascom Hall, Madison, Wis. Applications should be filed before February 15th of the scholastic year preceding that for which the appointment is desired.

Assistantships. An indefinite number in every department. Salary varies, depending upon the amount of time spent in teaching. In addition to the regular stipend received, the holder is exempt from the payment of the non-resident tuition ($100 a semester). He pays, however, the general fee of $27.50 per semester.

Forest Products Laboratory Research Assistantships. In accordance with the regulations of the U. S. Civil Service Commission, a limited number of students who show unusual ability in research may be appointed as student research assistants by the Forest Service and Bureau of Plant Industry. Entire time given to lecture or class work in the University and to research in the Laboratory. Number appointed depends upon funds available. Applications should be sent, with testimonials, to Director of Forest Products Laboratory, Madison, Wis. before March 1st of the academic year preceding that during which such appointments are to be held. Stipend, $200 to $480 a year, and remission of laboratory fees.

Fritzsche Brothers Fellowship in Pharmacy. Offered by the Fritzsche Brothers of New York. Holder is to do research work in plant chemistry with special reference to the *Monardas* and related problems. Stipend, $500 a year.

Gorham (Annie) Fellowship. Open to any graduate student. Stipend, approximately $400 a year.

Graduate Research Fellowships in Engineering. Three. Appointed for period of two years, subject to satisfactory service. Open to graduates of engineering colleges of recognized standing, who should have had one or two years' of graduate study, teaching or engineering experience. Stipend, $900 for first year, $1000 for second year.

Graduate Scholarships. Twenty-two. Open to all graduates of the University of Wisconsin or of other American or foreign colleges and universities, who have been given full admission to the Graduate School on the basis of official transcripts. Stipend, $250 a year.

By special provision authority is conferred upon the faculties of Beloit, Carroll, Lawrence, Milton, Milwaukee-Downer, and Ripon colleges to nominate annually to the faculty of the University of Wisconsin one member of their respective senior classes as a suitable candidate for a university scholarship.

Hollister Fellowship in Pharmacy. Established by wills of Mr. and Mrs. Albert H. Hollister. Annual income from $10,328 is allotted to a graduate student upon recommendation of the Department of Pharmacy.

Honorary Fellowships. Forty-eight. Election is by the Graduate Committee upon recommendation of a Graduate Division or a department. Restricted to persons who have already held academic honors, such as fellowships or teaching or research appointments and to visiting professors from other colleges and universities. No compensation is attached to these positions except the remission of the non-resident tuition and of the incidental portion ($12) of the general fee ($27); no teaching service is required. Awards made without application on the part of students.

Honorary Scholarships. Number not to exceed the number of paid university graduate scholarships. Only those persons are eligible who have received the baccalaureate degree at least one year previous to nomination. No compensation but exemption from payment of non-resident tuition fee and from incidental portion of general fee. Awards made without application on part of students.

Industrial Fellowships in Agricultural Experiment Station. In May, 1934, the following fellowships were in force. All of these fellowships are filled and are not open for applications.

ABBOTT LABORATORIES FELLOWSHIP, for study of the effect of iron and copper therapy on hemoglobin content of blood of infants. $500.

ALLIED MILLS, INC. FELLOWSHIP, for research on effect of different temperatures of oil extraction upon digestibility and biological values of protein of soy-bean meal. $2000.

AMERICAN CYANAMID COMPANY FELLOWSHIP, for study of cyanamid as an agent for the control of club-root of cabbage. $250.

CHICAGO MEDICAL MILK COMMISSION FELLOWSHIPS. Three. For study of occurrence and significance of certain streptococci in milk and milk products. $3000.

CORN INDUSTRIES RESEARCH FOUNDATION FELLOWSHIPS. Two. For study of corn starch chemistry and composition of corn as related to its industrial use. $2000.

DAIRY AND ICE CREAM MACHINERY AND SUPPLIES ASSOCIATION FELLOWSHIP, for study of factors involved in formation of sediment in homoginized milk. $750.

FRASCH (ELIZABETH BLEE) FUND FELLOWSHIPS. Five. For study of the biochemistry of nitrogen fixation by associative action of bacteria and leguminous plants. $6000.

GAME RESEARCH FELLOWSHIP. Supported by a group of Wisconsin sportsmen and conservationists, for the study of management of Wisconsin game birds. $1600.

INTERNATIONAL CANCER RESEARCH FOUNDATION FELLOWSHIP, for the study of pathological cell multiplication in plants. $1500.

KICKAPOO DEVELOPMENT CO. FELLOWSHIP, for the study of apple diseases in southwestern Wisconsin. $350.

LEVER BROS. CO. FELLOWSHIPS, for study of nutritive value of fats. Four. $6000.

MIDWEST CANNING CORPORATION FELLOWSHIP, for studies of corn diseases. $2100.

MILWAUKEE COUNTY MILK PRODUCERS' ASSOCIATION FELLOWSHIP, for demonstrational work on value of milk in human nutrition. $3200.

NATIONAL RESEARCH COUNCIL FELLOWSHIPS. Two. One for study on the influence of radiation upon absorption and assimilation of nitrate by the young wheat plant. $750. One for studies in physiology of reproduction in the pigeon. $700.

N. V. POTASH EXPORT MY. FELLOWSHIP, for study of forms of potash or kinds of minerals that exist either naturally in soils or are formed therein through addition of potash fertilizers. $1800.

PFIZER (CHARLES) AND CO. INC. FELLOWSHIP, for study of use of citric acid and salts in dairy manufacturing. $3250 a year.

QUAKER OATS CO. FELLOWSHIPS, for study of nutritive value of oatmeal by-products. Two. $6000.

RARE CHEMICALS INC. FELLOWSHIP, for study of bovine mastitis and methods of controlling this disease. $3000.

RED STAR YEAST PRODUCTS CO. FELLOWSHIP, for study of physiology of yeast organisms. $1000.

SQUIBB (E. R.) AND SONS FELLOWSHIP, for investigations of anemia resulting from pregnancy and from nutritional causes and reproduction studies on milk diets. $1800.

THIOPHENE PRODUCTS CO. FELLOWSHIP, for study of value of organic sulfur, particularly of Thion and Sulbumin, as a supplement to the ration of growing chicks and laying hens. $2500 a year.

U. S. MALTSTERS' ASSOCIATION FELLOWSHIP, for study of utilization of barley in the malting industry, particularly to determine the effects of barley variety and cultural practices dealing with the production of barley upon the general factor of malting quality. $1000.

WISCONSIN ALUMNI RESEARCH FOUNDATION FELLOWSHIPS. Three. For research involving the commercial application of laboratory findings dealing with the separation and purification of starch and starch products obtained from agricultural crops. $7500. Also one for the study of activation of milk by ultra-violet light. $1000.

Laird (Harriet Remington) Fellowship. Established by the will of the late John M. Olin in memory of the sister of Mrs. Olin. The net income from this fund of $10,000 shall, either yearly or biennially, as the Regents may determine, be used as a fellowship fund to be awarded to some woman graduate student selected by the faculty of the University. Stipend, $400 to $600 annually.

Legislative Scholarships. Fifty. Available to non-residents of Wisconsin. Awards made on the basis of previous scholastic record. Carries exmption from payment of the non-resident tuition fee ($100 per semester).

Omicron Nu, Wisconsin Chapter, Scholarship. Open to either graduate or undergraduate students. Stipend, $200 to $250 a year.

Research Assistantships. A number of research assistantships are available to graduate students at rates of compensation depending upon the amount of service rendered.

Special Fellowships in Engineering. From time to time cooperative fellowships are offered by various industrial establishments. In this case the fellow carries on research work on some special problem relating to the particular industry; the compensation varies with the amount of work done and importance of the project.

Tripp Scholarship. Established by will of the late J. Stephens Tripp. Scholarship open to residents of Sauk County, undergraduates as well as graduates. Stipend, $600 a year.

University Fellowships. Forty-eight. Appointments open to all graduates of the University of Wisconsin or of other American and foreign colleges and universities who have been given full admission to the Graduate School on the basis of their official transcripts. Awards are usually made to especially talented students who are candidates for the Ph. D. degree, but exceptions to this rule are often made. Stipend, $600 a year.

Wisconsin Scholarships. Available only to graduates of the University of Wisconsin. To be held only for a period of three semesters with a stipend of $450 for the period.

WOMEN'S MEDICAL ASSOCIATION OF NEW YORK CITY, Dr. Rose Cohen, Secretary, Fellowship Committee, 36 West 90th St., New York, N. Y.

Jacobi (Mary Putnam) Fellowship. Founded 1907, for study in medical sciences. Open to a woman, endorsed by the Head of the department in which her previous work has been done. Stipend, $1000 a year. Available for study in any American university or abroad. Due to the present status of the fellowship fund the award for 1934-35 will not be made.

WOMEN'S MEDICAL COLLEGE OF PENNSYLVANIA, Philadelphia, Pa.

Woman's Medical College of Pennsylvania Scholarships. The income from funds left for the purpose by Ann Preston, M. D., Robert J. Dodd, M. D., H. Adaline Thompson, M. D., Hannah Matilda Dodd, Arethusa L. Forbes, Edward T. Dobbins, Isaiah V. Williamson, Joseph E. Gillingham, F. L. Sharpless and Sarah Cushing enables the College to assist annually a limited number of women of good character and through preparatory education who are unable to secure a medical education without such aid. $3000 for the same purpose has been given by Dr. Henry Leffman as a memorial to his mother, Sarah Ann Laffman; also $2000 in memory of an alumna of the College to be known as the Frances Linton Sharpless Fund. Other special scholarship endowments have also been established. Many of these do not yield sufficient income to pay a full year's tuition charges, and are either awarded as partial scholarships or are awarded periodically when a sufficient amount of income has accumulated to pay one full year's tuition.

To receive consideration as a candidate for a scholarship a student must show an average record of academic work equivalent to grade " C " (80%) or over. Awards are made to first year students in exceptional cases only. Applications should be sent to the Dean of the College before April 1st, and must be in the handwriting of the applicant, accompanied by satisfactory certificates as to age, health, character, education and need of financial assistance. Stipends vary.

WILSON COLLEGE, Chambersburg, Pa.

Wilson College Fellowships. Six. Open to women who are graduates of Wilson College, for study in any other American university or abroad. Stipend, $600 a year. Applications should be filed by March 1st with the President, on special form furnished on request.

YALE UNIVERSITY, New Haven, Conn.

In general, fellowships are reserved for students who have already done graduate work and who are candidates for a degree. In cases of equal merit preference is given to applicants in residence at Yale. (*) refers to fellowships which may be combined to yield an income for several fellowships of approximately $900 each, which are awarded only to graduates of Yale College of the highest attainments. Applications should be filed by March 1st with the Graduate School.

Abernethy (John J.) Fellowship.* Founded by John J. Abernethy. Open to graduates of Yale College. Stipend, income from fund of $10,000.

Barge (Benjamin F.) Scholarship. Founded by Benjamin F. Barge. Occasionally awarded as a graduate scholarship to graduates of Yale College. Stipend, income from fund of $5000.

Bidwell (Marshall S.) Fellowship.* Founded by Benjamin Douglas Silliman. Open to graduates of Yale College. Available for pursuit of non-professional studies in New Haven. Fellowship may be held for not more than two consecutive years. Stipend, income from fund of $11,000.

Binney (Edwin) Fellowship in Geology. Founded by Mr. and Mrs. Edwin Binney, 1925. Open to men who are graduates of Yale College or Sheffield Scientific School. Awarded during period of study for the Ph. D. degree in geology. Available in this University. Stipend, income from fund of $11,000.

Bishop Museum Fellowships. Two. Founded under an agreement between the Bernice Pauahi Bishop Museum, of Hawaii and Yale University. Open to students who have completed at least one year of graduate work at an institution of high standing. Preference is given to those who have a doctor's degree. Available for study and research in anthropology, botany, zoology, geography or geology in the islands of the Pacific. Stipend, $2000 a year.

Calhoun (Edward Thomas) Scholarship. Founded 1928 by Mrs. Lida T. Calhoun, for research in pathology in the School of Medicine. Open to men and women with an M. D. degree. Stipend, income from $1000. Applications should be filed by December 1st with the Department of Pathology, 333 Cedar St., New Haven, Conn.

Clark Scholarship. Founded by Mr. Sheldon Clark, of Oxford, Conn. Awarded to the applicant from the senior class of Yale College who has attained highest rank in the studies of the course. Available for resident and non-professional study. Stipend, income of the sum of $6200.

Coxe (Alexander Brown) Memorial Fellowships. One or more. Founded by the family of Alexander Brown Coxe, 1927. Open to men and women who have the M. D. or Ph.D. degree. Available in this University for study in the biological and medical sciences. Maximum stipend, $2500 a year.

Cushing (William Harvey) Memorial Fellowship. Founded 1928 by Dr. Harvey Cushing for research in surgery. Open to men and women with the M. D. degree. Stipend, income on $25,400. Applications should be filed by December 1st with Department of Surgery, 333 Cedar Street, New Haven, Conn.

Cutler (Carroll) Fellowship. Founded by Mrs. Frances E. Cutler. Open to men. Stipend, income of fund of over $11,000.

Cutler (Susan Rhoda) Fellowship. Founded by Mrs. Frances E. Cutler. Open to women. Stipend, income from fund of over $11,000.

Cuyler Fellowship.* Founded by Thomas De Witt Cuyler, Cornelius C. Cuyler and Miss Eleanor deGraff Cuyler. Open to graduates of Yale College. Stipend, income from fund of $10,000.

Dana (James Dwight) Fellowship. Founded upon the James Dwight Dana Memorial Fund, one-half of the income of which is devoted to this purpose, the other half to promote original research by the members of the Geological Faculty or by advanced students. Preference is given to graduates of Yale College or Sheffield Scientific School. With the approval of the Professors of Geology, the fellow may puruse his studies outside of New Haven. Fellowship may not be held for more than two years. Stipend, $500 a year.

DeForest Fellowship in Mathematics. Open to men who are graduates of Yale College. Awarded for distinction in undergraduate mathematical studies. Available in this University for the study of mathematics. Stipend, $300 a year.

Douglas Fellowship.* Founded by Mrs. Samuel Miller of New Haven. Open to graduates of Yale College. Available in New Haven for the pursuit of non-professional studies. Fellowship may be held not more than three years. Stipend, income from fund of $10,000.

Eaton (Daniel C.) Graduate Scholarship in Botany. Founded by Mrs. Caroline K. Eaton. Open only to members of the senior classes in Yale College and the Sheffield Scientific School. Stipend, income from fund of $5000.

Eldridge (Ellen Battell) Fellowships.* Two. Founded by Mrs. Azariah Eldridge of Yarmouth, Mass. Open to graduates of Yale College for resident study in New Haven. May be held not longer than three years. Stipend, income from fund of $24,000 divided between the two fellows.

English (Alice Kimball) Traveling Fellowship. Founded 1893 by Mr. and Mrs. Henry F. English for study of architecture, painting or sculpture in Europe. Open to graduates of the Yale School of the Fine Arts. Stipend, $1200 annually. Applications should be filed by May 1st on special form furnished by the Yale School of the Fine Arts.

Fleischmann Fellowship in Organic Chemistry. Gift from the Fleischmann Laboratories, operated by Standard Brands, Inc. Open to candidates with Ph. D. degree in organic chemistry. Stipend, $800 a year.

Foote Fellowship.* Two or more. Founded by a bequest from Harry W. Foote of New Haven. Open to graduates of Yale College. Available in New Haven for the pursuit of graduate studies. Stipend, income from fund of $25,000 divided between two or more fellows.

Hadley (Arthur Twining) Scholarship. Awarded to assist students of the University in the publication of meritorious dissertations or results of investigations. Stipend of $200 sometimes divided.

Hooker (Henry Daggett) Fellowship in Botany. Founded 1930 by Mary Davenport Hooker in memory of her son. Offered annually for graduate study in plant physiology. Original amount, $15,000.

Howard (Austin F.) Scholarships. One or more. Founded by bequest from James T. Howard, of St. Johnsbury, Vt. Preference given to graduates of Yale College. Stipend, income from fund of $10,000.

Hurtt (Scott) Fellowship.* Founded by Mrs. Sarah I. Hurtt of New York City. Open to graduates, of not more than four years standing, of Yale College. May be held for three years, one of which may be spent in New Haven and the other two at any foreign university or the American School in Athens or Rome. Stipend, income from fund of $12,000.

Iddings (Joseph Paxon) Scholarship in Petrology. Founded by Mrs. Estelle Iddings, Cleveland. Open to students competent to carry on research in petrology in the Sheffield Scientific School. Stipend, $450 a year.

Indiana Fellowship in Anthropology. Open to a holder of the doctorate or an advanced graduate student familiar with ethnology and linguistic field methods, for research in the ethnology and linguistics of the Indians of Indiana and the adjoining states. Stipend, $1000. For field work, $500.

Ives (Charles Linnaeus) Fellowship. Founded 1924 by Mrs. Bessie W. Ives for research in pathology. Open to men and women with the M. D. degree. Awarded to a student who shall have distinguished himself in the department of pathology. Available for study in any American university or abroad. Stipend, income on $10,000.

Ives (Mary E.) Fellowship in Psychology. Founded 1908 by Mrs. Mary E. Ives. Awarded annually to a woman graduate of any college of good standing who has taken a bachelor's degree with distinction and has been recommended by the professors of psychology, preference being given to a student who has had one year of graduate work. No person shall hold the fellowship for more than three years. Original gift, $10,000. Stipend, income.

Larned Fellowships.* Three. Founded by a bequest from Mrs. Irene Larned of New Haven, augmented by a bequest from Mrs. Urania B. Humphrey of Norfolk, Conn. Open to graduates of Yale College for pursuit of graduate studies in New Haven. Stipend, income from $21,000 divided among the three fellows.

Lilly (Eli) and Company Graduate Fellowship in Organic Chemistry. Founded by Eli Lilly and Company of Indianapolis. Open to men and women who have enrolled for the Ph. D. degree in chemistry, who have completed two years of graduate study, and who show capacity for original work in some special field of organic chemistry. Available in this University. Stipend, $800, plus $100 for special equipment and chemicals used in research.

Lilly (Eli) and Company Research Fellowship in Organic Chemistry. Founded by Eli Lilly and Company of Indianapolis. Open to men and women who have a doctorate degree. Available in this University for research in organic chemistry. Stipend, $3000 a year plus $2000 for expenses involved in investigations.

Loomis (Henry Bradford) Fellowship in Chemistry. Founded by Henry Bradford Loomis. Open to graduates of Yale College and the Sheffield Scientific School and to graduates of other institutions who have spent at least one year in the study of chemistry in the graduate school of Yale University. Awarded to the candidate who passes the best competitive examination in chemistry. Holder must be candidate for the Ph. D. degree and make chemistry his chief study. Stipend, $1350 a year.

Loomis Fellowship in Physics. Founded by Francis E. and Henry Bradford Loomis. Open to recent graduates of Yale College and Sheffield Scientific School and to graduates of other institutions who have spent one year in study of physics in Yale Graduate School. Awarded to the candidate passing the best competitive examination in physics. Holder must be candidate for the Ph. D. degree and make physics his chief study. Stipend, $1350 a year.

Macy Fellowship.* Founded by a bequest from William A. Macy. Open to graduates of Yale College. May be held for three years, for pursuit of non-professional studies in New Haven. Stipend, income from fund of $10,000.

Matcham (Charles Arthur and Margaret Ormrod) Traveling Fellowship. Founded 1928, by Charles O. Matcham and his sisters, Catherine M. Campbell and Dorothy M. Chapman. Open to men, white citizens of the United States or Great Britain, who are graduates of the Department of Architecture, Yale School of the Fine Arts, having been enrolled for not less than two years and having successfully completed at least two years in some recognized college, university or school of technology previously. The recipient shall at no time have been the holder of any other traveling scholarship. Available for study of architecture in Europe. Stipend, $1000 a year. Applications should be filed by May 1st on special form furnished by the School of the Fine Arts, Yale University.

Metz Research Fellowship in Organic Chemistry. Founded by Dr. H. A. Metz. Open to men and women who have a doctorate degree. Available in this University for study in organic chemistry or biochemistry. Stipend, $1500 a year.

Miller (Mary) Fellowship. Founded 1930, by a bequest from Alanson Douglas Miller. Open to any member of the Graduate School, preferably a recent graduate of Yale College. Original amount, $9500.

National Tuberculosis Association Research Fellowships in Organic Chemistry and Biochemistry. Two. Founded by the Association. Open to men and women who are holders of the Ph. D. degree. Available in this University for chemical research on the tubercle bacillus. Stipend, $1800 to $2000 a year.

Page Scholarship in Anthropology and the Science of Society. Founded by Edward D. Page, 1901. Open to seniors in the Sheffield Scientific School. Available in this University for research in anthropology. Stipend, income from fund of $14,000.

Plainfield Scholarship. Founded by Edwin Miller of Plainfield, Conn. Open to worthy students from the County of Windham, Conn., preferably from the town of Plainfield. Occasionally awarded for graduate work. Stipend, $500 a year.

Research Fellowship in Bacteriology. Open to students who have completed the work for the Ph. D. degree. Awarded on recommendation of Professor Rettger for special research in bacteriology in the Graduate School. Stipend, $1200 a year.

Ridgway (Gertrude Knight) Memorial for Dr. George H. Knight. Founded 1923, for research work on nervous and mental diseases. Open to men and women usually with the M. D. or Ph. D. degree for study in Yale University. Stipend, $1000. The balance of the income of the fund of $81,600 is used to support the work in neuro-anatomy.

Robinson (Henry C.) Fellowship. Founded in the name of Mrs. Mary Robinson Cheney of Hartford, Conn., and her sister, Miss Eliza Robinson. Stipend, income from fund of $5000.

Scholarships for Advanced Work in Forestry. Four. Founded 1928 and 1930, by Mrs. W. H. Sage and Mrs. C. B. Wood. Open to men, who have completed collegiate work in forestry, for research in forestry in Yale University. Stipend, $500 a year.

Seessel Fellowships. Two. Founded from the income of the Theresa Seessel Fund given by Dr. Albert Seessel. Preference given men or women who have obtained their doctorate and are able to carry on original research in one of the three departments of biological studies: Physiology (including physiological chemistry), zoology and botany. Stipend, $1400 a year.

Silliman Fellowship.* Open to graduates of Yale College. Fellowship may not be held more than three years. Stipend, income from fund of $10,000.

Sloane (John) Fellowship in Physics.* Founded by John Sloane of New York. Open to graduates of Yale College for resident study in New Haven. Recipient acts as assistant in Sloane Physics Laboratory. Fellowship may be held not more than three years. Stipend, income from fund of $10,000.

Smith (A. Homer) Research Fellowship in Organic Chemistry. Open to men and women graduates of universities, who have already received the doctorate and have demonstrated their ability to carry on original research in organic chemistry and biochemistry. Stipend, $2500; limited allowance to aid in defraying cost of materials used in investigation. This fellowship calls for ten months of actual service.

Squibb (E. R.) and Sons Research Fellowship in Organic Chemistry. A gift each year for special research in biochemistry and chemical synthesis. Stipend, $5000.

Stanley (Anthony D.) Memorial Fellowship. Open to men who are graduates of Yale College. Awarded for distinction in undergraduate mathematical studies. Available in this University for study of mathematics. Stipend, $280 a year.

Sterling Research Fellowships. Twenty-two awards in 1933-34. Founded by John W. Sterling. Open to men and women who have the Ph. D. degree or its equivalent. Available in this University, except in unusual cases where a fellow has been at Yale for a year or more and wishes to go abroad for some specific study. Stipend, $1000 to $2500 a year.

Strathcona Memorial Fellowships in Transportation. Five. Founded by Lord Strathcona. Open to men with first degree from an institution of high standing. Preference given to such persons or sons of such persons as have been for at least two years connected in some manner with the railways of the Northwest. Available in this University for study of construction, equipment, and operation of railroads. Stipend, $1000 a year.

University Fellowships. Ten. Supported by income of various funds, including National Currier Scholarship Fund. Preference given to those who have already spent at least one year in graduate study and have shown capacity for original work. Stipend, $350 to $800 a year.

University Scholarships. About forty. Maintained by the University. Stipend, tuition.

Waterman (Thomas Glasby) Scholarships. Not more than three. Founded from estate of Thomas Glasby Waterman. Occasionally awarded to graduates of Yale College of not more than two years standing. Stipend, income from fund of $40,000 divided among the holders.

Winchester (William Wirt) Traveling Fellowship. Founded 1895 by Mrs. Jane E. Winchester for study abroad in architecture, painting or sculpture. Open to men and women who are graduates of the Yale School of the Fine Arts. Stipend, $1200 a year. Applications should be filed by May 1st on special form furnished by the Yale School of the Fine Arts.

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This index lists all fellowships and scholarships which have distinctive names, and it groups under the subjects those which are restricted to particular sciences. No heading of "General" or "Unrestricted" is used as practically every university has one or more such fellowships or scholarships. The text should be consulted in regard to these to supplement the information contained under the subject entries.

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BULLETIN
OF THE
NATIONAL RESEARCH COUNCIL

NUMBER 95

FUNDS AVAILABLE IN THE UNITED STATES FOR THE SUPPORT AND ENCOURAGEMENT OF RESEARCH IN SCIENCE AND ITS TECHNOLOGIES

Third Edition

Compiled for
Research Information Service
by
CALLIE HULL and CLARENCE J. WEST

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
OF
THE NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.
1934

Price $1.00

507.7

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National Research Council

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461076

PREFACE

The Research Information Service, in offering the Third Edition of " Funds Available in the United States for the Support and Encouragement of Research in Science and its Technologies," desires to call attention to the following facts:

The Scope of the Bulletin. Information is presented concerning funds available for the encouragement and support of research in the form of *medals, prizes, grants,* and *institutional* funds. The term " institutional funds " is used for those funds which are donated or set aside for research within an institution or society, but which are not available to those outside.

Funds for fellowships and scholarships are not included as they form a separate publication, " Fellowships and Scholarships for Graduate Work in Science and Technology," which was revised simultaneously with the material for the funds publication and appeared as Bulletin no. 94 (June, 1934).

No federal funds are included, and no government departments or bureaus, with the exception of the Smithsonian Institution which administers some funds not strictly governmental.

The Arrangement of the Bulletin. The entries are arranged alphabetically by name of the organization administering the fund, and funds are arranged in the same manner under the organization. An index to the names of funds listed, to subjects covered and to classes of funds (medals, prizes, grants) appears at the end of the publication.

The Field Surveyed and Information Requested. Questionnaires were sent to about 500 universities and colleges, societies and foundations requesting full information about funds. Second, third and fourth requests followed in an effort to make the bulletin as complete as possible. The information was not always returned in the desired form, nor was it always as full as it might have been, but on the whole the cooperation of the organizations approached was cordial.

Amount of Money Reported for Research. From the material in the Bulletin it is not possible to make any accurate statement as to the money spent annually for scientific research in the United States. Many organizations which reported funds declined to give the amount; many found it impossible to separate the part used for research from that used for administration; and many have given the amount of the principal, but not the annual expenditure.

It is hoped, however, that the publication will be a helpful and suggestive contribution to those interested in the status of scientific research in the United States, and the encouragement given to it through gifts and specified funds.

FUNDS FOR SCIENTIFIC RESEARCH

ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA, Philadelphia, Pa.

General and Special Funds for maintenance of the institution, support of the research staff, explorations, publications, library, etc. Annually available, $60,000.

Hayden Memorial Geological Award, for distinguished work in geology or paleontology. Awarded triennially. Recipient selected by a committee of the Academy.

Leidy (Joseph) Medal. Established 1923 by Joseph Leidy, II, for an award (bronze medal and honorarium) to be given every three years for the best publication, exploration, discovery or research in the natural sciences in such particular branches thereof as may be designated. Recipient selected by a committee of the Academy.

ALABAMA, UNIVERSITY OF, University, Ala.

Graham (Isabella Hummel) Prize. Established March, 1932, by Dr. John Y. Graham, for the encouragement of graduate study in the Department of Zoology and to aid in securing better trained teachers in the Department. Original amount, $1000. Present amount, $1071. Annually available, $50. During his life the donor reserves the right to name the recipient of this scholarship, which will be available for use either at the Marine Biological Laboratory, Woods Hole, Mass., or at the University of Alabama.

AMERICAN ACADEMY OF ARTS AND SCIENCES, 28 Newbury St., Boston, Mass.

Permanent Science Fund. By an agreement and declaration of trust made September 5, 1928, the Boston Safe Deposit and Trust Company has constituted itself a trustee to receive gifts or bequests which shall be held as a Permanent Science Fund. The financial administration of the fund is by the Company. The income will be paid over to the Academy, which has undertaken to disburse the money in the aid of scientific research through the Council of the Academy, acting on the recommendation of a Committee on the Permanent Science Fund. Annually available (1933-34), $5000.

Rumford Fund. Established 1796, by Benjamin, Count Rumford, for the award of premiums to investigators for discoveries in heat or light tending most to promote the good of mankind, and for grants towards researches in light or heat. X-ray research has been considered as coming within the scope of the fund. Grants are awarded on the recommendation of a standing committee of the Academy (Rumford Committee) of seven members, to cover the cost of equipment or of publication of researches on heat and light. The grants are assignable to any duly qualified resident of North America. In recent years the grants have varied from $100 to $500. Original amount, $5000. Present amount, $82,748. Annually available, $3230 (1933-34).

Warren (C. M.) Fund. Established 1891, by Cyrus Moors Warren, for the encouragement of chemical research. Original amount, $6000. Present amount, $18,965.66. Annually available $934.37 (1933-34). Awards are made on the recommendation of a standing committee of the Academy consisting of seven members. Grants are made to cover the cost of special apparatus or unusual chemicals not ordinarily available in well equipped research laboratories. In recent years these grants have varied from $100 to $500.

AMERICAN ACADEMY OF OPHTHALMOLOGY AND OTOLARYNGOLOGY, W. P. Wherry, Executive Secretary, 1500 Medical Arts Bldg., Omaha, Neb.

Academy Research Fund. Established 1915, for eye, ear, nose and throat research. Annually available, $3000 to $5000. Awarded by the Council of the Academy.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE, Smithsonian Institution Bldg., Washington, D. C.

American Association Prize. Amount of prize, $1000. Awarded annually to an author of a noteworthy contribution to science presented at the annual meeting of the Association. First award in December, 1923.

Permanent Fund for Advancement of Science. Partly apportioned to specific objects, $238,641. The total amount of unrestricted income annually available varies, but $3000 or more is assigned to a committee on grants for research. Applications for grants should reach the Permanent Secretary before October 1st to be considered by the committee and, if approved, appropriated at the annual meeting in December.

AMERICAN ASSOCIATION FOR THE STUDY OF GOITER, J. R. Yung, Corresponding Secretary, 500 Rose Disp. Bldg., Terre Haute, Ind.

Prize of $300 and Two Honorable Mentions. Established 1930, to stimulate original research in the subject of goiter, especially as to its basic cause. Annually available, $300. The essay must be written in English, authenticated and in the hands of the Secretary sixty days prior to annual meeting of the Association, which is usually held in June.

AMERICAN ASSOCIATION OF CEREAL CHEMISTS, M. D. Mize, Secretary, 836 Omaha Grain Exchange, Omaha, Neb.

Osborne (Thomas Burr) Medal. Established 1926, to encourage and recognize notable research in cereal chemistry. The award is a gold medal granted irregularly.

AMERICAN ASSOCIATION OF ENGINEERS, 8 South Michigan Boulevard, Chicago, Ill. M. E. McIver, Secretary.

Clausen Medal. Established June, 1926. Awarded annually to the person who has contributed most to the social and economic status of the engineer. Original amount, $1000.

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, J. P. D. Hull, Business Manager, Box 1852, Tulsa, Okla.

Research Fund. Authorized in 1923 for research problems in connection with petroleum geology. In general, this fund is not available to research students; it is used at the discretion of the Executive Committee. Present amount, $1356.

AMERICAN ASSOCIATION OF STATE HIGHWAY OFFICIALS, W. C. Markham, Secretary, National Press Bldg., Washington, D. C.

Bartlett (George S.) Award. Established 1931, by friends of George S. Bartlett, to perpetuate the spirit of friendship and helpfulness which he brought into his work in the highway field. Capital, $1500. The recipient of the award is selected by the Presidents or Chairmen or their representatives of the American Association of State Highway Officials, the American Road Builders' Association and the Highway Research Board.

AMERICAN ASSOCIATION OF VARIABLE STAR OBSERVERS, Leon Campbell, Recorder, Harvard Observatory, Cambridge, Mass.

Pickering (David B.) Nova Medal. Established 1918, to be awarded to the original discoverer of each new star found visually.

AMERICAN ASTRONOMICAL SOCIETY, Raymond S. Dugan, Secretary, Princeton University, Princeton, N. J.

Cannon (Annie J.) Prize in Astronomy. Established June, 1933, by gift of Dr. Annie J. Cannon, to be awarded first in December, 1934 and thereafter at intervals of three years, subject to the judgment of the Council of the American Astronomical Society. The award is to be made to women for distinguished contributions to astronomy or for similar contributions in related sciences which have immediate application to astronomy. It is open to women of all countries. The award consists of a token or certificate and a money award determined by the Council, not exceeding the interest on the fund of $1000.

AMERICAN CHEMICAL SOCIETY, Mills Bldg., Washington, D. C.

Priestley Medal. Established 1923, to be awarded every three years for distinguished services to chemistry. Present fund, $1094.

AMERICAN CHEMICAL SOCIETY, CHICAGO SECTION, W. M. Hinman, Sec., Box 803, Chicago, Ill.

Gibbs (Willard) Medal. Established 1910, by William A. Converse, for eminent work in and original contributions to pure or applied chemistry. Present fund, $3000. Selection by a Jury elected from the American Chemical Society membership by the Chicago Section.

AMERICAN CHEMICAL SOCIETY, NEW YORK SECTION, 52 East 41st St., New York, N. Y.

Nichols (William H.) Medal. Established 1902, for stimulating original research in chemistry. Present fund, $1700. Annually available, $98.

AMERICAN CHEMICAL SOCIETY. NORTHEASTERN SECTION, A. R. Davis, Secretary, Massachusetts Institute of Technology, Cambridge, Mass.

Richards (Theodore William) Medal. Established 1931. Awarded not oftener than once in two years for conspicuous achievement in chemistry. Present amount, $8100.

AMERICAN CHEMICAL SOCIETY, PITTSBURGH SECTION, W. P. Yant, Chairman, U. S. Bureau of Mines, Pittsburgh, Pa.

Pittsburgh Award. Established 1933, to honor those who have rendered distinguished service to chemistry in this community. Members of the Pittsburgh Section, or in exceptional cases non-members, who have done work worthy of note toward increasing chemical knowledge, promoting industry, benefiting humanity or advancing the Pittsburgh Section are eligible for consideration by the Committee. The award shall be a suitable medal or other form of recognition, selected by the Awards Committee.

AMERICAN CHEMICAL SOCIETY, WESTERN NEW YORK SECTION, M. L. Ross, Secretary, 3913 McKoon Ave., Niagara Falls, N. Y.

Schoelkopt (Jacob F.) Gold Medal. Founded 1930, by Jacob F. Schoelkopf, Sr., for the purpose of giving encouragement and recognition to the spirit of research in industry. Capital, $2000. Annually available, $80 (interest on investment).

AMERICAN COLLEGE OF RADIOLOGY, 2561 North Clark St., Chicago, Ill.

Gold Medal. Established 1923, by the Board of Chancellors of the American College of Radiology, to encourage radiologists to promote the science through scientific research. It is awarded as a recognition of outstanding achievements at such times and intervals as the Board may choose.

AMERICAN CONCRETE INSTITUTE, 7400 Second Blvd., Detroit, Mich.

Turner (Henry C.) Medal. Established 1927, for notable achievements in or service to the concrete industry. To be awarded from time to time, not oftener than once each year. Not restricted to members of the Institute nor to achievements of any given period.

Wason (Leonard C.) Medals. Established 1915, one for each year's most meritorious paper and one for research. Restricted to members of the Institute.

AMERICAN CONGRESS OF PHYSICAL THERAPY, Nathan H. Palmer, Secretary, 30 North Michigan Ave., Chicago, Ill.

Golden Key Award. A medal given for meritorious service.

AMERICAN DENTAL ASSOCIATION, RESEARCH COMMISSION OF THE, Dr. C. T. Messner, Secretary, Public Health Service, Washington, D. C.

Each year at the time of the meeting of the American Dental Association an amount is appropriated to stimulate research in dental or scientific subjects. In 1933 this was $11,500. $8500 was granted for the support of two fellowships at the Bureau of Standards for the study of dental materials; $750 to New York Institute of Pathology; $750 to the University of Louisville; and $700 to Johns Hopkins University, Harriet Lane Home. All applications should be addressed to Secretary, Research Commission, on special forms which are available for that purpose and may be obtained upon request.

AMERICAN FISHERIES SOCIETY, Seth Gordon, Secretary, Investment Bldg., Washington, D. C.

Prizes are occasionally offered from the regular income of the Society for research in certain lines.

AMERICAN FOUNDRYMEN'S ASSOCIATION, 222 West Adams St., Chicago, Ill.

McFadden (William H.) Fund. Established 1923, by Wm. H. McFadden, to encourage and stimulate meritorious effort in the industry of making metal castings. Original fund, $5000. Present fund, $5000. Awards made on recommendation of Board of Awards, consisting of the last seven living past presidents. Conferred as an award, prize, medal or scholarship.

Obermayer Co. (S.) Award. Established 1920, by the Company, to encourage and stimulate meritorious effort of workers in the foundry. Original amount, $1000. Present amount, $1000. Contest limited to men who are foremen or workers in foundries or in some department of a plant operated in connection with a foundry. Subject to the decision of a committee of judges, following rules laid down by Board of Awards.

Penton (John A.) Fund. Established 1923, by John A. Penton, to encourage and stimulate meritorious effort in the industry of making metal castings. Original amount, $5000. Present amount, $5000. Conferred as an award, prize, medal or scholarship. Awards made on recommendation of Board of Awards, consisting of the last seven living past presidents.

Seaman (Joseph S.) Fund. Established 1923, by Joseph S. Seaman, to encourage and stimulate meritorious effort in the industry of making metal castings. Original amount, $5000. Present amount, $5000. Conferred as an award, prize, medal or scholarship. Awards made on recommendation of Board of Awards, consisting of the last seven living past presidents.

Whiting (J. H.) Fund. Established 1923, by J. H. Whiting, to encourage and stimulate meritorious effort in the industry of making metal castings. Original amount, $5000. Present amount, $5000. Conferred as an award, prize, medal or scholarship. Awards made on recommendation of Board of Awards, consisting of the last seven living past presidents.

AMERICAN GAME PROTECTIVE ASSOCIATION, Augustus Houghton, Secretary, Investment Bldg., Washington, D. C.

Grouse Investigation Fund. Established 1924, by various donors, for the study of the ruffed grouse disease. Original amount, $15,000. Annually available, $5000. Expended by a special committee.

AMERICAN GAS ASSOCIATION, 420 Lexington Ave., New York, N. Y.

Beal Medal. Awarded first in 1897. Established by the Beal family for the best technical paper submitted at meetings of the Association.

Munroe (Charles A.) Award. Awarded in recognition of outstanding contribution by an individual toward the advancement of the gas industry. The first award was made in 1929.

Various projects for improving the use of gas in industrial heating operations and in developing new industrial processes where gas heat can be used to advantage are financed by annual appropriations from the Association. The projects include pure scientific research and the development of apparatus for interpreting industrial heating processes in a practical manner. They are assigned to the institution or organization deemed best equipped as to personnel, equipment and experience for successfully carrying on the work.

AMERICAN GENETIC ASSOCIATION, 510 Victor Bldg., 724 Ninth St., N. W., Washington, D. C.

Meyer (Frank N.) Memorial Medal. Established 1918, for distinctive service in the field of plant introduction. Original fund, $1000.

AMERICAN GEOGRAPHICAL SOCIETY, Broadway at 156th St., New York, N. Y.

By far the greater part of the total budget of approximately $100,000 a year is expended upon research and publication. Although all fields of geography come properly within the scope of the Society's interest, especial attention is now being devoted to Hispanic America, methods of survey, polar problems, pioneer settlement and land utilization.

Cullum Geographical Medal. Established 1894, by George W. Cullum, for distinguished service in geographical discovery or in advancement of geographical science. Original capital, $5000.

Daly (Charles P.) Medal. Established 1900, by Charles P. Daly, to be awarded to explorers, writers and men of science who have contributed to the advancement of geographical knowledge. Original fund, $5000.

Livingstone (David) Centenary Medal. Established 1913, by the Hispanic Society of America, to be awarded for scientific achievement in the field of the geography of the South Hemisphere.

Morse (S. F. B.) Medal. Established 1902, by S. F. B. Morse, to encourage geographical research. Original fund, $1000.

AMERICAN GLADIOLUS SOCIETY, Roscoe Huff, Secretary, Spohn Bldg., Goshen, Ind.

Awards and Medals. A fund of $3500 was established in 1910 to stimulate interest and promote the culture and development of the gladiolus. The cash awards and the medals vary from year to year.

AMERICAN HOME ECONOMICS ASSOCIATION, 617 Mills Bldg., Washington, D. C.

Rockefeller (Laura Spelman) Fund. Established September 1, 1926, by the Laura Spelman Rockefeller Memorial, to make a study of the more significant experiments and new developments in home economics education, particularly with respect to the study of child care and the education of parents. Original amount, $34,000 for four years, $10,000 available for first year and $8000 for each of the three succeeding years. The original grant was later supplemented by $50,000 appropriated to carry forward the work begun under the original grant, payments to be made as follows: $10,000 in each of the five years within the period beginning September 1, 1929 and ending August 31, 1934; any balance unexpended as of August 31, 1935 is to revert to the Spelman Fund and/or be lapsed.

AMERICAN INSTITUTE OF CHEMISTS, 233 Broadway, New York, N. Y. H. S. Neiman, Secretary.

American Institute of Chemists' Medal. Established 1926. Awarded annually " for noteworthy and outstanding service to the science of chemistry and the profession of chemist in America."

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, 33 West 39th St., New York, N. Y.

District Prizes. The following district prizes may be awarded: 1. Prize for best paper. 2. Prize for initial paper. 3. Prize for branch paper. Each prize consists of $25 and a certificate and may be awarded annually in each of the ten geographical districts into which the Institute membership is divided.

Edison Medal. Established 1904, for meritorious achievement in electrical science, electrical engineering or the electrical arts. Original fund, $5000.

Lamme Medal. Established 1926, for meritorious achievement in the development of electrical apparatus or machinery. Original fund, $5160.

National Prizes (5). 1. Three best paper prizes, as follows: For engineering practice; for theory and research; for public relations and education. 2. Prize for initial paper. 3. Prize for branch paper. Each prize consists of $100 and a certificate and may be awarded annually at discretion of Committee on Award of Institute Prizes.

The Society participates in a number of joint awards as follows:

John Fritz Medal. *See* Fritz (John) Medal Corporation.

Herbert Hoover Medal. *See* American Society of Mechanical Engineers.

Alfred Noble Prize. *See* American Society of Civil Engineers.

Washington Award. *See* Western Society of Engineers.

AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS, 29 West 39th St., New York, N. Y.

Douglas (James) Medal. Established 1922, in memory of James Douglas, to be awarded for distinguished achievement in non-ferrous metallurgy. Original amount, $3250. Annually available, $145. Candidate selected by Committee of Award and approved by Board of Directors of A. I. M. E.

Hunt (Robert W.) Medal and Prize. Established 1920, by employees of Robert W. Hunt, to be awarded to that person or persons contributing to the Institute the best original paper or papers on iron or steel. Original amount, $7500. Present amount, $8400. Annually available, $375.

Johnson (J. E., Jr.) Award. Established 1921, by Mrs. J. E. Johnson, Jr., to bring encouragement, notice or distinction to young men who have made promise of achievement in branches of metallurgy or manufacture of pig iron. Original amount, $3000. Present amount, $3300. Annually available, $150. Candidates selected because of meritorious research, invention, contribution to professional literature or through other means publicly announced by the Directors of A. I. M. E.

Lucas (Anthony F.) Fund. Established 1922. The income is to be used to establish a medal to be awarded for distinguished achievement in the petroleum industry. Original amount, $6800. Income, $300.

Mudd (Seeley W.) Fund. Established 1929, by the family of Colonel Seeley W. Mudd. Income to be used for research in the non-ferrous field, which would be of particular benefit to young engineers. Original amount, $100,000. Annual income, $4500.

Rand (Charles F.) Foundation. Established 1930, by friends of Charles F. Rand. The income is to be available to support the various phases of the work of the Institute in which Mr. Rand was interested. Original amount, $9900. Annually available, $445.

Rocky Mountain Club Fund. Established 1928. In the recognition of community of interest between the Club and the Institute the two merged. The income from this fund is to be used for the benefit of the consolidated corporation but preferably to further the interest of the western mining engineers. Original amount, $109,500. Present amount, $109,700. Annual income, $4930.

Saunders (William Lawrence) Mining Medal. Established 1927, by W. L. Saunders, for distinguished achievement in mining. Original amount, $7000. Annually available, $315. Candidate selected by Committee of Award and approved by Board of Directors of A. I. M. E.

The Society also participates in a number of joint awards as follows:

John Fritz Medal. *See* Fritz (John) Medal Corporation.

Herbert Hoover Medal. *See* American Institute of Electrical Engineers.

Alfred Noble Prize. *See* American Society of Civil Engineers.

Washington Award. *See* Western Society of Engineers.

AMERICAN INSTITUTE OF THE CITY OF NEW YORK, 60 East 42nd St., New York, N. Y.

Medal. An award was established in 1932 to recognize outstanding scientific, engineering and industrial achievements that have a broad incidence on human welfare. The award consists of a gold medal and a citation. The membership of the American Institute is requested each year in April to submit the name of any person they wish considered for the medal. Information is collected on these and submitted to the Council on Awards, consisting of nine members of the American Institute, whose decision is approved by the Trustees. No more than four medals may be awarded in any one year.

AMERICAN LARYNGOLOGICAL ASSOCIATION, 2020 East 93rd St., Cleveland, Ohio.

Casselberry Prize Fund, for encouraging advancement in the art and science of laryngology and rhinology, to be awarded in part or as a whole, for a prize award, decoration or the expense for original investigation and research in the domains mentioned above. Sum available, $500. Particulars from Dr. Wm. V. Mullin, Secretary.

De Roaldes Prize (Gold Medal). Established 1908, to advance the science of laryngology and rhinology in the United States and Canada. Presented triennially to the writer of an original thesis. Original fund, $500. Present fund, $700.

AMERICAN LIBRARY ASSOCIATION, 520 North Michigan Ave., Chicago, Ill.

Oberly (Eunice Rockwood) Memorial Fund. Established 1923, by coworkers and friends of Miss Oberly, formerly Librarian of the Bureau of Plant Industry, U. S. Department of Agriculture, to stimulate the compilation of bibliographies in the field of agriculture or the natural sciences. Original amount, $1000. Present amount, $1060. Biennially available, the interest at 5 per cent on the investment. All contributions must be submitted to the Chairman of the Oberly Memorial Fund Committee, Miss Claribel R. Barnett, Librarian, U. S. Department of Agriculture, Washington, D. C.

AMERICAN MANAGEMENT ASSOCIATION FOR INSTITUTE OF MANAGEMENT, 20 Vesey St., New York, N. Y.

Gantt Medal Fund. Established 1932 by members of Institute of Management for the recognition of distinguished achievement in industrial management as a service to the community. Capital, $2,000. Annually available, $90. A gold medal and diploma of award are presented.

AMERICAN MATHEMATICAL SOCIETY, 501 West 116th St., New York, N. Y.

Bôcher Prize in Analysis. Established 1921, by various donors, in memory of Maxime Bôcher. To be awarded every five years for a paper on analysis published in the preceding five-year interval in a journal, on the editorial board of which the American Mathematical Society was officially represented at the time of publication of the memoir. Award must be to a member of the Society not more than fifty years of age at the time of publication of the memoir. Dissertations are not eligible for the prize. No author who has once received the prize shall again receive it. Present amount, $1188 (invested in securities the value of which is subject to market fluctuations).

Cole Fund. Established 1922, by F. N. Cole and others, for the award of two prizes.

The COLE PRIZE IN ALGEBRA is awarded every five years (next award will be made at the end of 1934) for a paper on algebra. The conditions of award are the same as for the Bôcher Prize.

The COLE PRIZE IN THE THEORY OF NUMBERS is awarded every five years (next award will be made at the end of 1936) for a paper on the theory of numbers. Conditions of the award are the same as for the Bôcher Prize. Original amount, $1000. Present amount $2093 (invested in securities the value of which is subject to market fluctuations). Annually available, about $140.

Moore (Eliakim Hastings) Fund. Founded in 1922, in honor of Professor Eliakim Hastings Moore, on the occasion of the twenty-fifth anniversary meeting of the Chicago Section of the American Mathematical Society. The interest on the fund is to be used at the discretion of the Council of the Society, for the publication of important mathematical books or memoirs or the award of prizes.

AMERICAN MEDICAL ASSOCIATION, 535 North Dearborn St., Chicago, Ill.

Fund of Committee on Scientific Research. Established 1900, to further meritorious research in subjects relating to scientific medicine and of practical interest to the medical profession. Annually available, varying amounts for grants-in-aid, not exceeding $500 each as a rule.

Fund of Committee on Therapeutic Research, to be used in connection with investigations conducted by accredited research workers, to determine the therapeutic action of drugs. Annually available, $2000.

Fund of Council on Physical Therapy, to be used in connection with investigations conducted by accredited research workers in the field of physical therapy. Annually available, $2000.

AMERICAN METEOROLOGICAL SOCIETY, W. R. Gregg, Treasurer, Weather Bureau, Washington, D. C.

American Meteorological Society Endowment Fund. Established in 1928, for the encouragement of meteorological research. Original amount, $2000. Present amount, $2000. Annually available, $85. Awarded by vote of Council when application is received.

Edson (Carroll E.) Fund. Established May, 1931, by Dr. Carroll E. Edson, for purposes of general research in meteorological matters. Original amount, $1000. Present amount, $1140. Annually available, $50. Awarded by vote of Council when application is received.

Life Membership Fund. Established in 1920, for any meteorological research. Original amount, $710. Present amount, $1570. Annually available, $75. Awarded by vote of Council when application is received.

Meisinger Aerological Research Fund. Established in 1924, for the encouragement of aerological research. Original amount, $528.60. Present amount, $1980. Annually available, $90. Committee must pass on manuscripts submitted, and if any is deemed worthy, vote the award to the author.

AMERICAN MICROSCOPICAL SOCIETY, J. E. Ackert, Secretary, Kansas State College, Manhattan, Kans.

Spencer-Tolles Fund. Established 1884, to stimulate and aid research in microscopic work. Original amount, $25. Present amount, $18,391. Annually available, $200. Restricted to members of the Society.

AMERICAN MUSEUM OF NATURAL HISTORY, THE, 77th St. and Central Park West, New York, N. Y.

Jesup (Morris K.) Fund. Established 1908, by Mr. and Mrs. Morris K. Jesup, for the promotion of research, exploration and publication. Present amount, $5,795,914. Annually available, $276,229 (as of 1933). Restricted to scientific purposes.

Special Funds Account. Established at various times by various donors, for special field work, preparation, publication, purchase of specimens and education. Present amount, $1,034,055. Annually available, $48,965 from income, and $127,698 from subscriptions (as of 1933). All funds are specially designated by donors.

AMERICAN OPHTHALMOLOGICAL SOCIETY, 2213 Walnut St., Philadelphia, Pa.

Medal for Research. Established 1919, for research in ophthalmology. Original fund, $1500. Present fund, $1500. Awarded by a committee of the Society. Not confined to members.

AMERICAN ORNITHOLOGISTS UNION, T. S. Palmer, Secretary, 1939 Biltmore St., Washington, D. C.

Brewster Memorial Fund. Established 1919, by friends of William Brewster, a former president of the Union, to encourage research in American ornithology by awarding a medal and honorarium to the author of the most important contribution on American ornithology during the preceding six years. Original amount, $5200. Present amount, about $10,000. Biennially available, from $800 to $1000.

Dwight Memorial Fund. Established 1929, in memory of Dr. Jonathan Dwight, Jr., a former president of the Union and an authority on the *Laridae,* to be used in the publication of short articles on gulls. Original amount, $300.

Students' Fund. Established to enable students working their way through college to maintain their membership in the Union while carrying on their studies. Original amount $500. The annual income covers the dues of five or six student members.

AMERICAN OTOLOGICAL SOCIETY, INC., Fifth Ave. and 103rd St., New York, N. Y.

Research Fund. Established 1925, for investigation of progressive deafness, including otosclerosis. Original amount $90,000 (donated by Carnegie Corporation). Present amount, $500,000 (increase through various donations). Annually available, interest on $500,000. Grants are made by a Board of Trustees, consisting of eight otologists who are members of the American Otological Society, three consultants and three lay advisers. Applications should be made to the Central Bureau of Research of the American Otological Society, 103rd St. and 5th Ave., New York, N. Y.

AMERICAN PHARMACEUTICAL ASSOCIATION, 2215 Constitution Ave., Washington, D. C.

Centennial Fund. Established 1877, by the Local Philadelphia Committee for Meeting of 1877 and members, to aid in the prosecution of original research. Original amount, $1107. Present amount, $5,740.94. Annually available, $185. Grants are made by the Council of the Association.

Ebert Prize Fund. Established 1873, by Albert E. Ebert, for a suitable prize for an essay containing an original investigation or for improved methods of determining merit. Original amount, $500. Present amount, $1,044.90. Annually available, $50. Essays must be presented at an annual meeting of the Association; the award is made by a Committee appointed by the Scientific Section of the Association.

Remington (Joseph P.) Honor Medal Fund. Established 1918, by the New York Branch of the American Pharmaceutical Association, for a gold medal to be awarded to the man or women who has done most for American pharmacy during the preceding year. Original amount, $1200. Present amount $1,303.59. Annually available, $40. Award made by past presidents of the Association.

Research Fund. Established 1916, from the profits from the sale of the National Formulary, to encourage investigation and research upon any subject relating to pharmacy or the collateral sciences. Original amount, $7043. Present amount, $64,486. Annually available, 50 per cent of the income until the fund amounts to $100,000, and then the entire income. Grants are made by the Council of the Association upon recommendation of the Committee on Pharmaceutical Research.

AMERICAN PHILOSOPHICAL SOCIETY, 104 South Fifth St., Philadelphia, Pa.

Magellanic Gold Medal. Established 1786, by John Hyacinth de Magellan, for the best discovery or invention annually in navigation, astronomy or natural history. Original amount, 200 guineas. Present amount, $4,610.87.

Penrose Fund. Established 1932, by R. A. F. Penrose, Jr., the income to be used for general purposes of the Society. Capital, $3,864,802. Annually available, $20,000 for research.

AMERICAN PUBLIC HEALTH ASSOCIATION, 450 Seventh Ave., New York, N. Y.

Grants have been made since 1921 to the Committee on Administrative Practice. In 1933 a grant from the Commonwealth Fund in the sum of $3,683.29 was made available for the continuation of diphtheria and scarlet fever studies.

Sedgwick Memorial Medal Fund. Established 1926, by donors, most of whom were former students of Professor William T. Sedgwick at Massachusetts Institute of Technology, for the purpose of awarding a medal for distinguished service in public health, not oftener than once a year. Present amount, $1940.

AMERICAN REFRACTORIES INSTITUTE, 2202 Oliver Bldg., Pittsburgh, Pa.

Research and technical investigations on specific problems pertaining to the manufacture and improvement of refractories, with the intention of benefiting both manufacturers and consumers of refractory materials, are financed by subscriptions from members amounting to approximately $15,000 yearly, and are carried on in the Testing and Research Divisions at Mellon Institute of Industrial Research, Pittsburgh, Pa.

AMERICAN RAILWAY ASSOCIATION, Engineering Division, 59 East Van Buren St., Chicago, Ill.

American Railway Association Fund. $8000 annually is appropriated to the Engineering Division for the investigation of stresses in railroad track.

AMERICAN SCHOOL OF PREHISTORIC RESEARCH Old Lyme, Conn.

Gardiner (David) Memorial Fund. Established 1933, by Miss Sarah D. Gardiner, the income to be used for any purpose the Trustees of the School may see fit. Annually available, about $10,000. Applications should be filed with Dr. George Grant MacCurdy, Director.

AMERICAN SOCIETY FOR STEEL TREATING, W. H. Eiseman, Secretary, 7016 Euclid Ave., Cleveland, Ohio.

Howe (Henry Marion) Medal. Established 1922, to stimulate the Transactions (official publication) of the Society. Awarded to the author of the paper of highest merit presented in the Transactions during the year.

AMERICAN SOCIETY FOR TESTING MATERIALS, 260 South Broad St., Philadelphia, Pa.

Dudley (Charles B.) Medal. Established 1925, as an annual award to the author or authors of a paper presented before the Society of outstanding merit constituting an original contribution on research in materials. It commemorates the name of the first president of the Society. The value of the medal, which is in gold, is approximately $100.

Marburg (Edgar) Lecture. Established 1925, for the purpose of a lecture to be given at annual meetings of the Society by leaders in their respective professions, describing the outstanding developments in the promotion of knowledge of materials. The lecture carries an honorarium of $200. It commemorates the name of the first secretary of the Society. The funds for the Dudley Medal and Marburg Lecture are kept together and represent an investment account of approximately $7000.

Research Fund. This fund, begun in 1926, is to be used to further research work within the field of engineering materials carried on by committees or other agencies under the direction of the Society. The fund amounts to (December, 1933) $8200 and is augmented by contributions from Society surplus when possible.

Funds are raised from time to time for investigative work in the field of materials by the committees. At present (December, 1933) the Society holds for certain of its committees the sum of approximately $18,000 which is being expended for investigations.

AMERICAN SOCIETY OF CIVIL ENGINEERS, 33 West 39th St., New York, N. Y.

Collingwood Prize for Juniors. Established 1894, by Francis Collingwood, for an annual award of a cash prize and an engraved certificate to the author of a paper describing an engineering work with which the writer has been directly connected, or recording investigations contributing to engineering knowledge, some essential part of which was made by the writer, and which contains a rational digest of results. Any mathematical treatment must show immediate adaptability to professional practice. Accuracy of language and excellence of style will be considered factors. Original amount, $1000. Present amount, $1000. Annually available, $50. Restricted to the Juniors of the Society.

Croes (J. James R.) Medal. Established 1912, for the award of a gold medal annually to such paper as may be judged worthy, and be next in order of merit to the paper to which the Norman Medal is awarded; or, if the Norman Medal is not awarded, then to a paper, if any, which shall be judged worthy of the award of this prize for its merit as a contribution to engineering science. Annually available, $60.

Freeman Fund. Established 1924, by John R. Freeman, to aid and encourage young engineers, especially in research work; for underwriting the cost of publications on hydraulic science; or assisting in the translation or publication in English of works in foreign languages pertaining to hydraulics. A traveling scholarship has been established from the income of the fund. Original amount, $23,410. Present amount, $26,300. Annually available, $1600 to $1800.

Hering (Rudolph) Medal. Established 1924, by the Sanitary Engineering Division of the Society, for a bronze medal to be awarded to the author of a paper which contains the most valuable contribution to the increase of knowledge in, and to the advancement of, the sanitary branch of the engineering profession. Original amount, $1562. Present amount, $460. Annually available, $25. All original papers dealing with water works, sewerage works, drainage, refuse collection and disposal or any branch of sanitary engineering which are presented to the Society in finished form, whether presented to the Sanitary Engineering Division or otherwise, shall be open to the award, provided that such papers shall not have been previously contributed or published elsewhere. The paper for which the medal is awarded shall be recommended by a committee of three members of the Division appointed for the purpose by the Executive Committee of the Division, which committee shall review the recommendation and act upon it not later than October 1st. Competition is restricted to members of the Society.

Laurie (James) Prize. Established 1912 in honor of the first president of the Society, for a cash prize and an engraved certificate to the author of such paper as may be judged worthy of the award and to be next in order of merit to the paper to which the Rowland Prize is awarded; or if the Rowland Prize is not awarded, then to a paper, if any, which shall be judged worthy of the award of this prize for its merit as a contribution to engineering science. Annually available, $40.

Noble (Alfred) Prize. Established 1929, by engineers and others in honor of Alfred Noble, Past-President of the American Society of Civil Engineers and of the Western Society of Engineers, for the purpose of perpetuating his name and achievements. The award is made to a member of any grade of either the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers or the Western Society of Engineers, for a technical paper of particular merit accepted by any of the foregoing societies for publication, in whole or in abstract, in any of their respective technical publications, provided the author, at the time the paper is accepted in practically its final form by the proper committee of the Society publishing the paper, is not over thirty years of age. The prize consists of $500 in cash and a certificate. The amount may be changed from time to time by action of the Board of Direction of the American Society of

Civil Engineers. The recipient of the prize is selected by a committee of five, consisting of one representative of each Society; the award is based upon papers published by each Society within the twelve months preceding July 15th of each year.

Norman Medal. Established 1872, by George H. Norman, for a medal to be awarded for a paper which shall be judged worthy of special commendation for its merit as a contribution to engineering science. Original amount, $1000. Present amount, $1000. Annually available, $85. All original papers presented to the Society by members of any class, and published in the Transactions and in special issues of Proceedings during the year for which the medal is awarded, shall be open to the award, provided such papers shall not have been previously contributed in whole or in part to any other association, nor have appeared in print prior to their publication by the Society, nor have been published in the Transactions in any previous year. Papers written jointly by members and nonmembers are not eligible.

Rowland (Thomas Fitch) Prize. Instituted by the Society in 1882 and endowed in 1884, by Thomas Fitch Rowland, for an annual award of a cash prize and an engraved certificate, preference being given to papers describing in detail accomplished works of construction, their cost and errors in design and execution. Original amount $1222. Present amount, $1222. Annually available, $60. Not restricted to members of the Society.

Wellington (Arthur M.) Prize. Established 1921 and endowed by Engineering News-Record, for an annual award of a cash prize and an engraved certificate for papers on transportation on land, on the water or in the air. Original amount, $2000. Present amount, $2150. Annually available, $75. Not restricted to members of the Society.

The Society also participates in a number of joint awards as follows:

John Fritz Medal. *See* Fritz (John) Medal Corporation.

Herbert Hoover Medal. *See* American Institute of Electrical Engineers.

Washington Award. *See* Western Society of Engineers.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, 51 Madison Ave., New York, N. Y.

Research Fund. Established 1919, for determining and disseminating engineering knowledge pertaining to the profession of heating and ventilating, and to the equipment and apparatus utilized by the profession at large. An allotment of 40 per cent of the dues of members and associates is reserved for research. This amount is supplemented by contributions from other organizations and individuals engaged in the industry. Cooperative agreements for research are in force with the Universities of Illinois, Kansas, Minnesota, and Wisconsin, Texas Agricultural and Mechanical College, Carnegie Institute of Technology, Armour Institute of Technology, Case School of Applied Science, Yale University, Harvard School of Public Health and Michigan School of Mining and Technology. A laboratory is maintained at the U. S. Bureau of Mines Experiment Station, Pittsburgh, Pa.

AMERICAN SOCIETY OF MAMMALOGISTS, National Museum, Washington, D. C.

Allen Memorial Fund. Instituted in memoriam to Joel Asaph Allen, for publication only. Original amount, $10,000. Present amount, $10,465.57. Annually available, interest on fund. In addition to this, over $5000 is invested. The interest from the latter is now used for publication but it can be used in any way which the directors see fit, including use for research.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, 29 West 39th St., New York, N. Y.

Since 1920 an appropriation has been made annually by the Society for the encouragement and conduct of cooperative research projects in the field of mechanical engineering administered by committees. This appropriation provides for general supervision and secretarial service to the committees, while funds for actual experimental work come entirely from contributions by industry, the Engineering Foundation, etc. Over the past five years an average of $56,000 a year has been spent on this activity, of which sum the Society provided less than one-quarter.

A. S. M. E. Medal. Established 1920, for distinguished service in engineering and science. Not restricted to members of the Society. Ordinarily awarded only once a year.

Holley Medal. Established 1924, by George I. Rockwood, to be bestowed for some great and unique act of genius of engineering nature that has accomplished a great and timely public benefit.

Hoover Gold Medal. Established 1930, with the presentation of the first award to Herbert Hoover and, with his consent, named after him. Donated by Conrad N. Lauer, President of the Philadelphia Gas Works, to provide an award by engineers to a fellow engineer for distinguished and unselfish public service. Present amount, $15,000. May be awarded to an engineer in any nation.

Junior Award. Established 1914, by Henry Hess, for the best paper or thesis submitted by a Junior Member, through a gift of $1000, the income of which is to be awarded annually for a paper of exceptional merit by a Junior Member of the A. S. M. E.

Main (Charles T.) Award. Established by Charles T. Main, Past President of the Society, with a gift of $2500, the income to be awarded annually for the encouragement of research, good papers or other activity for the advancement of engineering by any member of the Society. This may take the form of a medal or of a cash prize and may be given in addition to any other award at the discretion of the Council.

Melville Medal. Established 1914, through a bequest of the late Rear Admiral George W. Melville, Past President and Honorary Member of the Society, to be presented for an original paper or thesis of exceptional merit, presented to the Society for discussion and publication; to encourage excellence in papers. It may be presented annually.

Spirit of Saint Louis Medal. Endowed by members of the Society and citizens of St. Louis, Mo., to be awarded for meritorious service in the field of aeronautical engineering. The medal will be awarded at the discretion of the Council of the Society at approximately three-year periods upon the recommendation of a Spirit of Saint Louis Medal Board of Award.

Student Award. Established 1914, by Henry Hess, through a gift of $1000, the income of which is to be awarded annually for the two papers of exceptional merit by members of the Student Branches.

Toltz (Major Max) Fund. $15,000 for assistance to students.

Warner (Worcester Reed) Medal. Provided for in the will of Worcester Reed Warner, to be bestowed on the author of the most worthy paper received, dealing with progressive ideas in mechanical engineering or efficiency in management.

The Society participates in a number of joint awards as follows:

John Fritz Medal. *See* Fritz (John) Medal Corporation.

Daniel Guggenheim Medal. *See* Guggenheim (Daniel) Medal Fund, Inc.

Alfred Noble Prize. *See* American Society of Civil Engineers.

Washington Award. *See* Western Society of Engineers.

AMERICAN SOCIETY OF PLANT PHYSIOLOGISTS, A. E. Murneek, Secretary, University of Missouri, Columbia, Mo.

Barnes (Charles Reid) Life Membership Fund. Established in 1930, to reward service. Original amount $1400. Present amount, $1440. Annually available, $100. Awarded to someone who has served the science of plant physiology as instructor or investigator in noteworthy manner.

Hales (Stephen) Prize Fund. Established 1927, to stimulate research. Original amount, $800. Present amount, $1100. Biennially available, $100. Awarded to residents of North America who have served the science of plant physiology in some noteworthy manner.

AMERICAN SOCIETY OF SWEDISH ENGINEERS, INC., 27 West 51st St., New York, N. Y.

Ericsson (John) Medal. Established 1926 as an award for scientific or technical achievement. Awarded to Swedish citizen, or American citizen of Swedish descent, for extraordinary achievement in the scientific or technical field.

AMERICAN WATER WORKS ASSOCIATION, 29 West 39th St., New York, N. Y.

Diven (John M.) Memorial Medal. Established 1925, for notable work performed by a member. Awarded annually at the Convention.

Goodell (John M.) Prize. Established 1931, by the Engineering News-Record, New York, N. Y., to provide an appropriate means by which the Association can record annually its appreciation of notable contributions by its members to the science and practice of water works development. Annually available, income from the sum of $1500. The recipient of the prize is selected each year by a committee of the Association.

AMERICAN WELDING SOCIETY, 33 West 39th St., New York, N. Y.

Miller (Samuel Wylie) Memorial Medal. In 1927 S. W. Miller established the Samuel Wylie Miller Medal, which at his death in 1929 ceased to exist. In 1929 the Society established the Samuel Wylie Miller Memorial Medal to be awarded annually for any meritorious achievement which, in the judgment of the Miller Medal Board of Trustees, has contributed conspicuously to the advancement of the art of welding and cutting. It is awarded to individuals only but of any country and of any age. The award for any calendar year is announced, and the medal with a suitable certificate is present at the annual meeting following the year for which the award is made.

ANTHRACITE INSTITUTE, 19 Rector St., New York, N. Y.

In cooperation with Pennsylvania State College, the Institute is conducting a study of the anthracite coal beds, an allotment of $12,000 having been made from the Institute's funds for the purposes of this investigation.

ANTIOCH COLLEGE, Yellow Springs, Ohio.

Antioch Industrial Research Institute. Established in 1929-30 through the assistance of New York friends for the investigation of problems of two classes: 1. those originating with the Institute, in which the problems are developed with a view toward commercialization and the return of resulting revenue to the Institute; 2. those which are submitted to the organization by outside industries, and for which conditions and financial arrangements are fixed by contract. The Institute has a basic annual budget of $30,000.

Fels (Samuel S.) Fund. Financed over a ten-year period, with a present annual budget of about $18,000 by a gift from Mr. Samuel S. Fels of Philadelphia. Its object is the investigation of all factors of the physical, mental and personality aspects of child development from the standpoint of heredity, and prenatal and postnatal environment.

See also Kettering Foundation.

ARIZONA, UNIVERSITY OF, Tucson, Arizona.

Douglas Fund for Scientific Research. Established by James S. Douglas, to carry on scientific research in engineering and its basic sciences. Original amount, $10,000. Annually available, approximately, $425. Must be used for purchase of equipment to conduct such investigations.

ARIZONA STATE MUSEUM, Tucson, Arizona.

The State spends a variable sum annually on investigation of archaeological ruins in Arizona. The amount for the present year is $660.

ARKANSAS, UNIVERSITY OF, Fayetteville, Ark.

In addition to Federal and State funds, moneys are appropriated for an engineering experiment station each year and there are annual budgets for the departments, a part of which they are encouraged to expend in research work.

An allotment of $600 to encourage individual research is made to the College of Arts and Sciences.

ASPHALT INSTITUTE, 801 Second Ave., New York, N. Y.

The Institute makes a limited appropriation annually to its research laboratory for the conduct of specific research work.

ASSOCIATION FOR RESEARCH IN NERVOUS AND MENTAL DISEASE, 70 East 77th St., New York, N. Y.

Research fund. Accumulated 1925 to 1929, to further work carried out in preparation for yearly scientific session. Capital, $4000. Income available. Money assigned at discretion of Board of Trustees through the Secretary of the Association, Dr. Thomas K. Davis.

ASSOCIATION OF AMERICAN PHYSICIANS, Dr. George Blumer, Treasurer, Room 308, 195 Church St., New Haven, Conn.

Kober Medal. Established by Dr. George Kober, to be awarded annually to a member who has contributed to the progress and achievement of the medical sciences or preventive medicine on the recommendation of the Council. Original amount, $1000.

ASSOCIATION OF MANUFACTURERS OF CHILLED CAR WHEELS, 1847 McCormick Bldg., Chicago, Ill.

About $50,000 is appropriated annually for research in the manufacture of chilled tread car wheels and locomotive wheels. This research is carried on in the Association laboratory, except when some work is desired for which the laboratory is not equipped. In such cases the Association finances the work outside.

ASSOCIATION OF MILITARY SURGEONS OF THE UNITED STATES, Army Medical Museum, Washington, D. C.

Wellcome (Sir Henry S.) Medal and Prize. Established 1916, by Sir Henry S. Wellcome of London, to encourage research on problems connected with the health of armies and the efficiency of the medical services. Annually available, a gold medal and $500. Competition is open to all medical officers, former medical officers, acting assistant and contract surgeons of the Army, Navy, Public Health Service, National Guard, U. S. Volunteers and of the Reserves of the United States, commissioned medical officers of foreign military services and all members of the Association.

ASTRONOMICAL SOCIETY OF THE PACIFIC, C. H. Adams, Secretary, 318 Merchants Exchange Bldg., San Francisco, Calif.

Bruce Gold Medal Fund. Established 1897, by Miss Catherine Wolfe Bruce, for distinguished service to astronomy. Original amount, $2500. Present amount, $3000. Annually available, $150.

Donohoe Comet Medal (bronze). Established 1890, by Joseph A. Donohoe, to commemorate the discovery of a comet. Original amount, $500. Present amount, $500. Annually available, $25.

BARNARD FREE SKIN AND CANCER HOSPITAL, 3427 Washington Ave., St. Louis, Mo.

General Endowment Fund. Established by various donors for the purpose of affording medical and surgical aid and nursing to persons suffering from skin diseases or cancer and diseases thereto allied, also research study of the diseases and the dissemination of knowledge in regard to them and their treatment. Capital, $756,108. Annually available, $23,300.

BATTELLE MEMORIAL INSTITUTE, 505 King Avenue, Columbus, Ohio.

Research Fund. Established 1925, by Gordon Battelle and Mrs. John G. Battelle, for the encouragement of creative research work in metallurgy, fuels and allied industries. Research facilities are available to industry and others under the sponsored project plan, whereby the project cost is borne by the sponsor.

BEHAVIOR RESEARCH FUND, Dr. Ernest W. Burgess, Director, 907 South Lincoln St., Chicago, Ill.

Established 1926 by friends of the Institute for Juvenile Research, a group of over 400 public-spirited citizens of Chicago, to assist in the understanding, treatment, amelioration and elimination of behavior problems in children and adults and to conduct and promote research and instruction in the field and the publication of the results thereof. The fund originally subscribed was $275,000 to be expended in a five-year period. During the last fiscal year ending September 30, 1933, $39,744 was expended. Research is carried on by staff members. The Behavior Research Fund works in close cooperation with the research work of the Illinois Institute for Juvenile Research. Monographs and case studies reporting research are published by the University of Chicago Press.

BISHOP (BERNICE P.) MUSEUM, Honolulu, Hawaii.

All income except that needed for building repairs, library and incidental expense is devoted to fostering research. Part of the income each year is set aside for field expenses, grants and honoraria for individuals not members of the regular staff.

BOSTON CITY HOSPITAL, Boston, Mass.

Sears (George G.) Fund. Established 1933, by Charles H. Tyler. $500,000 to be used for erection and equipment of a laboratory for Surgical Research and $500,000 to be held in trust, income only being used for salaries of workers in the Laboratory and for purchase of equipment as needed. Original amount, $1,000,000 (in process of being received).

BOSTON PSYCHOPATHIC HOSPITAL. 74 Fenwood Road, Boston, Mass.

Alcohol content of the blood and of the cerebrospinal fluid in abstainers, moderate and excessive drinkers. Funds from the Harvard Medical School, $500.

Biochemical factors in stuporous conditions. Research Fellowship of the Harvard Medical School, $3000.

Statistical analysis of the functional psychoses. Financed by a grant from the Rockefeller Foundation of $50,000 for not more than four years, beginning December 1, 1930.

Treatment of neurosyphilis. Financed by the State Department, Division of Mental Hygiene ($6675); also by Joseph M. Herman Medical Research Fund ($600).

BOSTON SOCIETY OF NATURAL HISTORY, 234 Berkeley St., Boston, Mass.

Walker Grand Honorary Prize. Established 1864, by Dr. William Johnson Walker, as a reward for scientific investigation or discovery in natural history. Prize of $500 (or $1000 in cases of extraordinary merit) available every five years. The Trustees of the Society award the prize for such investigation or discovery as they think deserving thereof, which has been first made known and published in the United States of America, and shall have been at the time of the award made known and published at least one year.

Walker Prizes in Natural History. Established 1864, by Dr. William Johnson Walker, to serve as encouragement to younger naturalists. Annually available, $60 (or $100 in cases of marked merit) for a first prize, and $50 for a second prize. Awarded for the best memoirs written in the English language on subjects proposed by the Board of Trustees. Open to all competitors. Memoirs must be in the hands of the Secretary on or before March 1st of the year for which the prize is offered.

BOSTON SURGICAL SOCIETY, T. H. Lanman, M. D., Secretary, 264 Beacon St., Boston, Mass.

Bigelow Medal Fund. Established 1915, by Dr. William Sturgis Bigelow, to award a medal for contributions to the advancement of surgery. Original amount, $5000. Present amount, $6734. Income available at whatever time and in whatever amount the Society may elect.

BOWDOIN COLLEGE, Brunswick, Maine.

Bowdoin Prize. Established 1928, by Mrs. William J. Curtis and children, to be given to that graduate or former member of the College, or member of its faculty at the time of the award, who shall have made, during the period, the most distinctive contribution in any field of human endeavor. The prize shall only be awarded to one who shall, in the judgment of the committee of award, be recognized as having won national and not merely local distinction, or who, in the judgment of the committee, is fairly entitled to be so recognized. Original amount, $20,000. Present amount, $21,000.

BOYCE THOMPSON INSTITUTE FOR PLANT RESEARCH, INC., Yonkers, N. Y.

The Institute was established September 24, 1924, by a gift from Colonel William Boyce Thompson, for fundamental research on plants and the dissemination of all information obtained to the public. Original amount, $3,000,000. Present amount, $8,500,000. Annually available, $320,000.

Frasch Fund for Agricultural Chemical Research. Established January 1, 1929, by the Elizabeth Blee Frasch Trust, for conducting research on " Effect of stimulative chemicals upon plant growth and metabolism " and "Insecticide and fungicide investigations". Original amount, $20,000 annually for a five year period. Present amount, $10,000 annually for a five year period, beginning January 1, 1934.

BRIGHAM (ROBERT B.) HOSPITAL, Boston, Mass.

Goldthwait (Joel and Ellen) Research Fund. Established 1915, for research in connection with the treatment of chronic disease. Original amount, $60,000. Present amount, $65,103. Annually available, $4400.

BROOKLYN BOTANIC GARDEN, Brooklyn, N. Y.

Special Research Fund for Plant Pathology, underwritten by friends of the Garden from year to year. $7500 annually. Pledge renewed for 1934.

In the distribution of the Botanic Garden budget for 1933, approximately $30,000 was spent for research.

BROOKLYN ENGINEERS' CLUB, 117 Remsen St., Brooklyn, N. Y.
George A. Dorfman, Secretary.

White (Alfred T.) Prize. Established 1912, by Alfred T. White, to recognize not only very distinctively meritorious technical accomplishments but also research and appreciative observation. Capital, $1000. The prize consists of $50 in cash, and a certificate stating that the prize is awarded for the most valuable paper presented by a member during the calendar year.

BUFFALO, UNIVERSITY OF, Buffalo, N. Y.

$8000 is annually available for scientific research at the University of Buffalo.

BUREAU OF SOCIAL HYGIENE, INC., 61 Broadway, New York, N. Y.

Grants of varying amounts. Established 1913, by John D. Rockefeller, Jr., for research in the general field of social hygiene, with special emphasis on work in criminology.

CALIFORNIA ACADEMY OF SCIENCES, San Francisco, Calif.

Approximately $90,000 is annually available from membership dues, from endowments by James Lick (land in business center of San Francisco now worth in excess of $500,000), Charles Crocker $20,000, William Hendrie $10,000, William Alvord $5000; a friend $10,000 to support a lecture course. Ignatz Steinhart made a bequest of $250,000 to the Academy to construct and equip an aquarium; Leslie Simson gave property worth $150,000 toward a new building in which there will be a Simson African Hall (wild life habitat groups), together with over 200 skins of African wild mammals. The Academy has also received a number of donations—$1000 to over $6000—to make possible the installation of wild life habitat groups. It maintains its exhibits free to the public, open every day in the year. In addition to the foregoing the Academy receives from San Francisco $40,000 to $50,000 per annum for the operation of its aquarium.

CALIFORNIA, UNIVERSITY OF, Berkeley, California.

Alexander (Annie M.) Endowment Funt. Established 1919, by Miss Annie M. Alexander, for the maintenance of the Museum of Vertebrate Zoology. Present amount, $225,000. Income 1932-33, $11,041.

Breon (Christine) Fund for Medical Research. Established 1931, by bequest of Christine Breon, for the support of medical research. Present amount, $614,718. Income 1932-33, $28,801.

Bureau of Public Administration. Established 1930, by the Rockefeller Foundation, for research in public administration. The Bureau is mainly supported by a continuing grant from the Rockefeller Foundation expiring June 30, 1936, and by grants from the General University Fund. The budget for 1933-34 is $44,830.

California Museum of Vertebrate Zoology. The expenditures for 1932-33 other than from the Alexander Endowment Fund (see above) were: Donations (Miss Alexander) $10,500; other donations $84.75; General University Fund $7468.

Claypole (Edith) Memorial Research Fund. Established 1915, by Agnes Claypole Moody and Norman Bridge, for investigation of problems in pathology by women students. Present amount, $22,503. Income 1932-33, $1057.

Coleman (John C. and Edward) Memorial Fund. Established 1921, by the heirs of John C. Coleman, for medical research relating to deafness. Present amount, $105,525. Income 1932-33, $4959.

Ehrman (Sidney Hellman) Memorial Endowment Fund. Established 1931, by Florence Hellman Ehrman and Sidney M. Ehrman, for support of a Chair of European History and other purposes to be specified by the donors. Until 1937, income not to exceed $2500 a year is to be devoted to the Institute of Social Sciences for historical research. Present amount, $250,000. Income 1932-33, $11,750.

Heller Committee for Research in Social Economics. Established 1923, by Mrs. E. S. Heller. Supported by annual donations.

Herzstein (Morris) Fund. Established 1929, by bequest of Dr. Morris Herzstein, for support of Chair of Biology in promotion of original biological and physiological research. Income beyond that needed for the Chair is utilized for the benefit of the Medical School. Present amount, $490,420. Income 1932-33, $21,957.

Herzstein Fund for Physiological Research. Established 1905, by Dr. Morris Herzstein, for research in physiology. Present amount, $3776. Income 1932-33, $177.

Hooper Foundation. The George Williams Hooper Endowment Fund was established in 1913, by Mrs. Sophronia T. Hooper, for medical research. Present amount, $1,350,655. Income 1932-33 $21,740. In addition to the income from the Endowment, in 1932-33 the Hooper Foundation expended the following sums: from the Coleman Fund, $3243; from donations, $37,510; from the General Fund of the University, $21,795.

Institute of Child Welfare. Established 1927, by the Laura Spelman Rockefeller Memorial, which provided its principal support until June 30, 1933. For 1933-34 the Institute will derive its principal support from a grant of $17,235 by the General Education Board and from a continuing grant of $13,000 per annum from the Spelman Fund of New York for Research in Adolescence. The total 1933-34 budget is $38,735.

Institute of Experimental Biology. Established 1930 to conduct research in biology. The budget for 1933-34 provides $26,621 for the institute, of which $10,000 is provided by the Rockefeller Foundation and $10,000 is derived from Morris Herzstein Fund (see above).

Jackson (Mathilde H.) Medical Research Fund. Established 1932, by bequest of Mathilde H. Jackson, for medical research and for the cure and remedy of throat, catarrah and lung diseases. Present amount, $7835. Income 1932-33, $442.

Lick Observatory Fund. Established 1888, by James Lick, for research in astronomy. Present amount, $90,018. Income 1932, $5401. Additional sums expended by the Observatory 1932-33 were derived from the following sources: Endowment income, $2562; donations, $6456; and from the General Fund, $58,750.

Mack (J. J. and Nettie) Memorial Foundation. Established 1928, by George H. and Irene M. Roos, for the study and relief of cancer and surgical diseases of the chest. Present amount, $100,000. Income 1932-33, $4700.

Mackenzie (J. H.) Endowment Fund. Established 1930, by J. H. Mackenzie, for the investigation and treatment of diseases of the nervous system, particularly Parkinson's disease. Principal, as well as income, is available for research. Present amount, $9136.76. Income 1932-33, $429.43.

Matson (Lillie B.) Research Fund. Established 1931, by bequest of Lillie B. Matson, for cancer research. Present amount, $2000. Income 1932-33, $94.

Medical Research Fund. Established 1929, by "A Friend," for cancer research. Present amount, $100,000. Income 1932-33, $4700.

Moffitt (James) Memorial Endowment Fund. Established 1928, by bequest of Mrs. Delia Moffitt, for medical research. Present amount, $20,000. Income 1932-33, $940.

Moffitt (Pauline Fore) Memorial Fund. Established 1930, by James K. Moffitt, for medical research. Present amount, $10,000. Income 1932-33, $470.

Murdock Boys Aid Memorial Fund for Child Welfare Research. Established 1931, by The Boys Aid Society of San Francisco, for research in matters pertaining to child welfare. At the present time only a portion of the income of the fund is available for research. Present amount, $86,100. Available income 1932-33, $457.75.

Pacific Coast Gas Association Fund (for Mechanical Engineering). Established 1928 from unexpended donation balances given by the Pacific Coast Gas Association. Principal, as well as income, is available for purchase of laboratory equipment for research in gas manufacture and utilization. Present amount, $3693.80.

Phelan (James) Research Fund. Established 1931, by bequest of James D. Phelan, for research. Present amount, $26,170. Income 1932-33, $1230.

Purington Research Fund. Established 1924, by bequest of Henrietta Elizabeth Purington, for the development and maintenance of the Pharmacological Laboratory of the Homeopathic Foundation. Present amount, $5000. Income 1932-33, $235.

Reeve (Charles Taylor) Foundation. Established 1929, by bequest of Charles Taylor Reeve, for the study and treatment of diseases and ailments of the human eye. Income is to be added to the fund until 1939. Present amount, $42,839.

Research Budget. Established 1917-18, for the encouragement of research by members of the faculty. For the year 1933-34, $76,500 will be available. Projects must be approved by the President with the advice of the Board of Research.

Scripps Institution of Oceanography. Established 1912, by the Scripps family, for oceanographic research. There is no permanent endowment fund but yearly grants are made in support of the Institution. The sum expended for research activities in 1932-33 was $63,277.

Smyth (William H.) Endowment Fund. Established 1926, but is as yet not productive. Its ultimate purpose is to stimulate research in the physical sciences. Present amount, $76,495.

Volkman Fund. Established 1930, by Mr. and Mrs. George F. Volkman, for support of the Institute of Social Sciences. Present amount, $5000.

Whiting Fund. Established 1897, by bequest of Harold Whiting, for the benefit of the Department of Physics. Utilized at present for support of fellowships. Present amount, $26,350. Income 1932-33, $1238.

Wiel (Henrietta Hecht and Lewis P.) Fund. Established 1923, by the Wiel family, for research in diseases of the heart and blood vessels. Present amount, $2000. Income 1932-33, $94.

In addition to those specific funds and activities already listed, many research activities are supported by departmental budgets. This is particularly true with respect to the scientific departments of the University. Only the principal contributions from friends of the University and from research foundations are here included.

COLLEGE OF AGRICULTURE

Based on figures for the year 1932-33, $1,031,690 was spent, for investigation, from funds at the disposal of the University, such as State appropriations, income from sales, etc. Included in the total expenditure was a portion of the income from the following funds and donations:

California Committee on the Relation of Electricity to Agriculture. Donated for the year 1932-33, $6642.70.

Dried Fruit Association of California. Donated for research in viticulture, 1932-33, $600.

Forestry Endowment Fund. Established 1921 from proceeds of sale of forestry stations. Present amount of fund, $29,200. Income 1932-33, $1372.

Giannini Foundation. Established 1928, by A. P. Giannini, for research in agricultural economics. Present amount of fund, $1,000,014. Income 1932-33, $45,887.

Kearney Bequest. Established 1909, by bequest of Theodore Kearney, the corpus consisting of property in Fresno County, California, now valued at $973,816. This fund is not productive at the present time.

Kellogg (W. K.) Endowment Fund. Established 1932, by W. K. Kellogg, for research in animal husbandry. Present amount of fund, $611,997. Income 1932-33, $24,020.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, Calif.

Biology Endowment Fund. Established 1928, to endow the Division of Biology of the Institute and to be applied in large measure to research. The exact apportionment of funds as between instruction and research cannot now be determined. Original amount, $1,050,000. The income annually available from the fund is $50,000.

Blacker (Robert Roe and Nellie Canfield) Scholarship and Research Endowment Fund. Established 1923, by Mr. and Mrs. R. R. Blacker, for support of graduate research work and—in such amounts as deemed wise by Board of Trustees—to provide for undergraduate scholarships. Original amount, $20,000. Present amount, $60,550. Annually available, $2700.

Bridge (Mae Manford) Research Maintenance Fund. Established 1925, by Mrs. Mae Manford Bridge, for the support of researches in physics in the Norman Bridge Laboratory of Physics. Original amount, $50,000. Present amount $326,000. Annually available, $15,000.

Carnegie Corporation Fund for the Support of Fundamental Researches in Physics and Chemistry. Established 1927, by the Carnegie Corporation, for the support of fundamental researches in physics and chemistry. Original amount, $200,000. An addition of $400,000 has been made by the Carnegie Corporation, making a total of $600,000. Annually available, $27,000.

General Education Board Fund for Graduate Instruction and Research in the Physical Sciences and in Biology. Established 1928, for the purposes indicated, and to be applied in large measure to research. The exact apportionment of funds as between instruction and research cannot now be determined. Amount, $2,050,000. Annual income, $90,000.

Gillis (Robert C.) Fund for Research in Physics. Established 1922, by Robert C. Gillis, for support of research in physics. Original amount, $100,000. Present amount, $100,000. Annually available, $4500.

Laws (Henry) Fellowship Fund. Established 1930, by Henry Laws, for fellowships for research in pure science. Original amount, $93,000. Present amount, $93,000. Annual income, $4000.

Lloyd-Smith (Josephine) Fund for Research in Chemistry. Established 1915, by Marjorie Fleming Lloyd-Smith and Wilton Lloyd-Smith, for support of research in chemistry. Amount, $155,000. Annually available, $7000.

Physics Endowment Fund. Established 1920, for support of research in physics. Original amount, $65,000. Present amount, $65,000. Annually available, $3000.

CARNEGIE CORPORATION OF NEW YORK, 522 Fifth Ave., New York, N. Y.

Carnegie Corporation of New York. Established 1911, by Andrew Carnegie, to promote the advancement and diffusion of knowledge and understanding among the people of the United States by aiding technical schools, hero funds, useful publications and by such other agencies and means as shall from time to time be found appropriate therefor. In 1917 the Charter was amended as to Canada and the British Colonies, $10,000,000 of the endowment being set aside for these. Aggregate original endowment of $125,000,000 increased to $135,000,000 by residuary bequest.

CARNEGIE INSTITUTE OF TECHNOLOGY, Pittsburgh, Pa.

Coal Research Laboratory. The Coal Research Laboratory was organized July 1, 1930, with funds granted by the United States Steel Corporation, the General Electric Company, the Westinghouse Electric and Manufacturing Company, the Koppers Corporation, the New York Edison Company, the Standard Oil Company of New Jersey, the Buhl Foundation of Pittsburgh and the Carnegie Institute of Technology. The fund is administered by the Carnegie Institute of Technology and is to be applied to fundamental research on coal and its products and to train students in fuel technology. There was an original grant of $74,500 for construction of the laboratories and their equipment. Annual contributions amount to $90,000. This support of the Coal Research Laboratory was pledged for an initial period of five years.

Metals Research Laboratory. The Metals Research Laboratory was organized July 1, 1924, under the title of the Bureau of Metallurgical Research. It was reorganized July 1, 1932, with an increase in available funds. It is now supported by the Carnegie Corporation of New York City which contributes $12,000 yearly and by the Carnegie Institute of Technology, which contributes $17,000 yearly. These funds are administered by the Carnegie Institution of Technology for the furtherance of scientific knowledge concerning the behavior of metals and alloys.

CARNEGIE INSTITUTION OF WASHINGTON, Washington, D. C.

Carnegie Institution of Washington. Established 1902, by Andrew Carnegie, with original endowment fund of $10,000,000, for the purpose of encouraging "investigation, research and discovery, and the application of knowledge to the improvement of mankind." Present endowment and reserve funds, $33,000,000, yielding an annual income of approximately $1,500,000. Appropriations are annually made for support of organized research activities within the Institution, as follows: Department of Embryology; Department of Genetics; Geophysical Laboratory; Division of Historical Research; Department of Meridian Astrometry; Mount Wilson Observatory; Nutrition Laboratory; Division of Plant Biology; Department of Terrestrial Magnetism; Tortugas (Marine Biological) Laboratory. In addition, a limited number of individual projects, having relation to major departmental problems, have been supported annually.

CENTRAL NEUROPSYCHIATRIC ASSOCIATION, Dr. Henry W. Woltman, Secretary Rochester, Minn.

A fund has been accumulating since 1921, the use of which has not yet been determined. Present amount, about $1000.

CHEMICAL FOUNDATION, THE, 654 Madison Avenue, New York, N. Y.

Under its Charter the Foundation uses a part of its funds for the advancement of chemical and allied sciences and industry in the United States.

CHEMICAL AND METALLURGICAL ENGINEERING. Sidney D. Kirkpatrick, Editor, 330 West 42nd St., New York, N. Y.

Chemical and Metallurgical Engineering Award. Established 1933, by Chemical and Metallurgical Engineering, McGraw-Hill Publishing Company, to encourage broader participation of chemical engineers in industry. Awarded biennially to the company in the process industries that, in the opinion of a committee of representative leaders in the industry and chemical profession, has made the most effective use of chemical engineering in any and all of its activities. The award consists of a bronze plaque.

CHEMICAL SOCIETY OF WASHINGTON, Cosmos Club, Washington, D. C.

Hillebrand Prize. Established 1926, for the encouragement of original research. The prize is an annual reward for a contribution or contributions during the preceding three years by members of the Chemical

Society of Washington. An individual may be nominated for the award by two members of the Chemical Society or may be considered by the Hillebrand Prize Award Committee itself. The Committee is appointed each year and consists of seven members of the Society. Capital, $1000. Annually available, $50.

CHEMISTS CLUB, 52 East 41st St., New York, N. Y.

Conné (Philip A.) Medal. Established 1932 by Madelyn Conné, to create in perpetuity a medal to be awarded annually for a specific scientific achievement to an individual responsible for a discovery in chemistry which has proven of value in the treatment of human disease. The medal is awarded annually by a Jury of Award appointed by the President or officer holding the equivalent position. The Jury of Award consists of five jurors, three of whom are to be members of The Chemists Club of New York, and of these three, two must be engaged in chemical teaching or research. The other two jurors are to be eminent members of the medical profession. Capital, $2500.

CHI OMEGA, 26 Cooper Building, Hyde Park, Cincinnati, Ohio.

National Achievement Award. Established 1930. Awarded in appreciation for notable accomplishment of women in various fields. Annually available, $500.

Service Fund. Established 1917, to finance, from time to time, research studies along social, economic and scientific lines.

CHICAGO, UNIVERSITY OF, Chicago, Ill.

Blair (Watson Keep) Research Fund. Established for research in the Medical Schools. Present amount, $50,322.

Capps (Joseph A.) Prize. Awarded for the most meritorious investigation in medicine or in the fundamental sciences, provided the work has a definite bearing on some medical problem. $500.

Culver (Helen) Fund. Established 1895, by Helen Culver, for increase and spread of knowledge within the field of the biological sciences. Present amount, $1,795,387.

Kuppenheimer (Alfred B.) Foundation. Established for medical research. Present amount, $649,167.

Kuppenheimer (Louis B. and Emma M.) Foundation. Established 1928, for the study of structure functions and diseases of the eye. Present amount, $250,000.

Lasker Foundation. Established 1928, by Albert D. and Flora W. Lasker, for research in causes, nature, prevention and cure of degenerative diseases. Present amount, $751,000 (Total pledge, $1,000,000).

Ogden Fund. Established for scientific investigation. Present amount, $558,817.

Physical Science Endowment Fund. Established 1927, by General Education Board, for research in physical sciences. Present amount, $1,600,000.

Ricketts (Howard T.) Prize. Established 1915, by Myra Tubbs Ricketts, for research in pathology or bacteriology. Present amount, $5331.

Rockefeller Foundation Gift. $30,000 for biological research.

Salisbury (Rollin D.) Memorial. Established 1923, by friends of Rollin D. Salisbury, for promotion of research in the fields of geology and geography. Present amount, $13,895.

Snow (George W.) Memorial Fund. Established for the Department of Astronomy. Present amount, $10,115.

Thomson (A. D.) Medical Fund. Established 1922, under the will of A. D. Thomson, for genito-urinary surgery. Present amount, $50,000.

Van Schaick (Gerard) Fund. Established 1925, by Gerard Van Schaick, for investigation of the pathology of the eye. Present amount, $10,000.

The following current funds are available (1933-1934):

Armour and Company. For research in pathology, $2400.

Corn Industries. For research in pediatrics, $2500; in physiology, $2500.

Cream of Wheat Corporation. For research in pediatrics, $6900.

Hansen (Christian) Laboratory Research Fund. For research in pediatrics, $5365.

Hertz (John D.) Fund. For research in medicine, $9101.

Macy (Josiah, Jr.) Foundation Fund. For research in physiology, $4000.

Milbank Fund. For research in infantile paralysis, $3644.

National Canners Association Fund. For research in nutritive value of food.

Quaker Oats Company Research Fund. For research in physiological chemistry and home economics.

Stieglitz (Julius) Fund. (Received from Chemical Foundation, Inc.) For research in chemistry, $8000.

Swift and Company. For fellowship in physiology, $5419.

CHILDREN'S FUND OF MICHIGAN, 660 Frederick St., Detroit, Mich.

Children's Fund of Michigan conducts a medical research laboratory in cooperation with the Children's Hospital of Michigan. Members of the staff of the Children's Hospital who wish to use the clinical material found there receive assistance of the staff of the research laboratory in pursuing any scientific quest.

CHILDREN'S HOSPITAL, Cincinnati, Ohio.

Proctor Foundation. Established 1927, by William Cooper Proctor, for pediatric research. Original amount, $2,000,000. Present amount, $3,000,000. The Foundation is affiliated with the University of Cincinnati and is planned to coordinate the research of the various organizations in Cincinnati and to provide ideal laboratory facilities for both the laboratory phases of the clinical investigation and for problems originating in the laboratory. There are at present two scholarships for men working in the Foundation or in the Pediatric Department of the College of Medicine of the University of Cincinnati. There are no grants or scholarships for non-residents. There is, however, provision for providing laboratory facilities for holders of research grants from other institutions.

CHRIST HOSPITAL INSTITUTE OF MEDICAL RESEARCH, Cincinnati, Ohio.

Fund for Medical and Scientific Research was established 1927, by James N. Gamble. The amount of the gift is not made public.

CINCINNATI, UNIVERSITY OF, Cincinnati, Ohio.

Ault (L. A.) Fund in Surgery. For research in surgery. $600.

Basic Science Research Fund. Established 1924, for research in basic science. Annually available, approximately $49,650.

Lithographic Research Fund. Established 1925, by the Lithographic Technical Foundation, for research in lithography. Annually available, approximately $16,000.

Tanners' Council Fund. Established 1924, by the Tanners' Council of America, to maintain and operate a laboratory of leather research. Annually available, $20,000.

CLARK UNIVERSITY, Worcester, Mass.

Citizen's Fund (Barton Fund). The income of $5000 is to be used for the aid of some one or more worthy native born citizens of the City of Worcester who may desire to avail themselves of the advantages of this institution. The benefits of this fund are available to graduate students only.

Dodge (Eliza D.) Fund. The income of $1000 is to be expended to help graduate students of limited means engaged in research work.

Field (John White) Fund. Established by Mrs. Eliza W. Field. The income of $500 is to provide for the minor needs of a scholar or fellow.

COLLEGE OF PHYSICIANS OF PHILADELPHIA, 19 South 22nd St., Philadelphia, Pa.

Alvarenga Prize. Established 1888, by Pedro Francisco da Costa Alvarenga of Lisbon, Portugal, for an essay upon any branch of medicine. Original amount, $4140. Present amount, about $6000. Annually available, $300. Essays may be on any subject in medicine, must not have been previously published and must be in English.

COLLEGE OF ST. CATHERINE, St. Paul, Minn.

Carroll (Mary A.) Memorial Prize. Established 1932, by Dr. Wm. C. Carroll, for outstanding work in science. Annually available, $50.

The average budget of the Order of the Sisters of St. Joseph, St. Paul, Minn., for study and research on the part of the faculty of the College is $5000.

COLORADO, UNIVERSITY OF, SCHOOL OF MEDICINE, Denver, Colo.

Elliott (Chester H.) Memorial Prize. Awarded for work in pathology. $50.

COLORADO ENGINEERING COUNCIL, 210 Gas and Electric Bldg., Denver, Colo.

Silver Medal. Established 1927, to encourage engineering education and to stimulate outstanding work by the engineering students in the three engineering colleges of Colorado. Awarded to the outstanding student of the Senior Class in each college and in gold occasionally to an outstanding Colorado engineer.

COLORADO FOUNDATION FOR RESEARCH IN TUBERCULOSIS, 1520 Nevada Avenue, Colorado Springs, Colo.

Endowment Fund. Established 1924, by many donors, to add to the sum of knowledge of the prevention and cure of tuberculosis. Present amount, $150,000. Annually available, $7000 to $14,000, depending on annual gifts to maintenance fund. No grants are made. Proceeds of endowment and maintenance funds are used to maintain a research laboratory at Colorado Springs, where work on tuberculosis research is conducted by a staff of paid and voluntary workers.

COLUMBIA UNIVERSITY, New York, N. Y.

Anonymous Fund for Cancer Research. The income is to be used for the work of the Institute of Cancer Research. Present amount, $10,000.

Barnard Medal. The residuary estate of the late President Barnard was left to the Trustees of Columbia College to constitute a fund under the name of the "Barnard Fund for the Increase of the Library," the income of which is to be devoted to the purchase of books, especially those relating to physical and astronomical science; but out of the income of this fund so much as may be necessary is to be applied in procuring a gold medal of the bullion value of not less than $200, to be styled the "Barnard Medal for Meritorious Service to Science," to be awarded every five years on the judgment of the National Academy of Sciences of the United States. Present amount, $59,600.

Bondy (Emil C.) Fund. The income is to be applied, first, toward investigation into the cause, prevention and cure of cancer and second, toward general research in medicine and surgery and their allied subjects. Present amount, $100,000.

Bull (William T.) Memorial Fund. Income is to be applied to meet the cost of conducting original research under the direction of the Department of Surgery. Present amount, $32,250.

Carpenter (Clarence) Fund. The income is to be used to promote cancer research. Present amount, $20,000.

Castner (Hamilton Young) Fund. The income is to be invested in such manner as shall most effectively encourage chemical investigation and research. Present amount, $282,710.

Chandler (Charles Frederick) Fund. The income is to be applied to the delivery and publication of at least one public lecture each year on some phase of the science of chemistry, etc. Present amount, $7500.

Class of 1889 Medal Fund. The income is to be applied to the cost of a medal to be awarded triennially to a graduate of the School of Mines or of any of the schools of applied science or architecture, who shall have distinguished himself by eminent achievement in any sphere of human effort. Present amount, $500.

Cock (Thomas F., M. D.) Prize Fund. Income is to be used to provide an annual prize to be known as the Thomas F. Cock, M. D., Prize, for the best thesis on puerperal fever. Present amount, $1125.

Crocker (George) Special Research Fund. The income is to be used in cancer research. Present amount, $1,415,000.

Dyckman Fund for the Encouragement of Biological Research. The interest is to be devoted annually to such object, consistent with the purposes of the gift, as shall be recommended by the Department of Zoology and approved by the President. Present amount, $11,500.

Harkness (Edward S.) Fund. The income is to be used for medical education and research. Present amount, $1,127,159.

Harkness (Edward S.) Fund for the Department of Surgery. The income is to be used for the department of Surgery in accordance with the terms of the gift. Present amount, $600,000.

Harkness (Mrs. Stephen V.) Fund. The income is to be used for medical education and research. Present amount, $1,426,940.

Hays (Walter) Memorial Fund. The income is to be used for the promotion of research at the College of Physicians and Surgeons. Present amount, $1000.

James (Dr. Walter B.) Fund. Income to be used for the benefit of the College of Physicians and Surgeons. Present amount, $50,000.

Lambert (Adrian) Fund. To be used for the study of suppurative diseases of the lungs and thorax. Present amount, $10,000.

Lee Fund. The income is to be used to meet the cost of equipment and research in the Department of Physiology. Present amount, $30,000.

Libbey (Jonas M.) Fund. The income is to be used to promote and support research and publish and distribute the results of such research in regard to the application of the principles of biological and pathological chemistry and electrochemistry and electro-physics to human need and welfare. Present amount, $216,763.

Meierhof (Harold Lee) Prize Fund. The income is to be awarded annually in recognition of some meritorious piece of research accomplished in the Department of Pathology. Present amount, $1000.

Mergentime (James Henry) Fund. To be used at the discretion of the Trustees to promote the study of organic chemistry. Present amount, $1,599.95.

Newberry (John S.) Prize Fund. The income is to be awarded annually as the John S. Newberry Prize, in the Department of Zoology. Present amount, $5000.

Ottmann (Madeleine L.) Research Fund. The income or principal is to be used for research in the Department of Neurology. Present amount, $50,000.

Peele (Robert) Prize Fund. The income is to be given annually to a member of the graduating class in mining and metallurgical engineering who shall have shown the greatest proficiency in his course of study. Present amount, $2000.

Peters (William Richmond, Jr.) Fund for Engineering Research. The income is to be applied to the work of research in the Department of Civil Engineering. Present amount, $60,000.

Phoenix Legacy. Bequeathed for the purpose of scientific instruction and research. Present amount, $1,259,994.

Pyridine Fund. $1500, given by the Ciba Company, for pharmacological study of their product, Coramine.

Rosenthal Fund for Medical Research. $2948 for cancer research.

Stevens Prize Fund. Income is to be awarded every three years for the best medical essay covering original research as determined by the committee in charge of the prize. Present amount, $1900.

University Publication Fund. The income to be expended to meet the cost of publishing works of scholarship and research through the Columbia University Press. Present amount, $401.19.

Van Praag (L. A.) Fund. To be used for research into the causes and cure of cancer. Present amount, $8000.

Wanger Melanin Fund. A gift, added to from time to time, from Mr. and Mrs. Walter F. Wanger for the study of the pharmacology of melanin.

Watson (Dr. William Perry) Foundation in Pediatrics. To establish a permanent fund, the annual income of which shall be given in cash to that member of the graduating class showing the most efficient work in the study of the diseases of infants and children. Present amount, $5200.

COMMISSION ON STANDARDIZATION OF BIOLOGICAL STAINS, H. J. Conn, Chairman, Geneva, N. Y.

Annual appropriations are received from the Chemical Foundation to meet the budget for standardization of and investigations concerning biological stains.

COMMITTEE OF REVISION OF THE PHARMACOPOEIA OF THE UNITED STATES OF AMERICA, 1930-1940, E. Fullerton Cook, Chairman, 43rd St. and Woodland Ave., Philadelphia, Pa.

Remington (Joseph P.) Research Fund. Following the recommendation of the Board of Trustees, the U. S. Pharmacopoeia Convention of 1930 voted the sum of $20,000 from the funds of the Convention as the start of a research fund in honor of Joseph P. Remington, Chairman of the Committee of Revision of the U. S. P. VIII and IX. This fund will be administered by the Board of Trustees and the income from it used in furthering research upon problems of the revision. It is expected that additional amounts will be added to this permanent fund from time to time.

The U. S. Pharmacopoeial Board of Trustees have also appropriated the following amounts during 1931, 1932 and 1933 for specific researches in the revision of official monographs: inorganic chemistry texts, $2000; organic chemistry texts, $3500; drug assay, $1600; volatile oils, $150; syrups, etc., $400. Total, $7650.

COMMONWEALTH FUND, 41 East 57th St., New York, N. Y.

Commonwealth Fund. Established 1918, by Mrs. Stephen V. Harkness. Its purpose is broadly philanthropic. Present amount, $41,000,000. Annually available $1,700,000. No funds are set aside by the Commonwealth Fund for the specific purpose of research, all appropriations being made by action of the Board of Directors with regard to specific proposals and requests.

CORDAGE INSTITUTE, 60 East 42nd St., New York, N. Y.

Study of Distribution of Hard Fiber Cordage. Established 1928. Original amount, $15,000.

CORN INDUSTRIES RESEARCH FOUNDATION, Wimmer Bldg., Indianapolis, Ind.

Research fund. Established March 17, 1933, to establish the dietary values of corn sugar (dextrose) and corn syrup by the scientific investigation of their basic nutritional properties in comparison with sucrose and other sugars. $25,000 for 1933-34. These studies are being undertaken at Columbia University, Harvard College, Iowa State University, Rochester University, University of Wisconsin and University of Chicago.

CORNELL UNIVERSITY, Ithaca, N. Y.

In addition to the several departmental appropriations, from fifteen to twenty-five per cent of which is used for research, there are the following special funds with incomes and purposes as indicated.

Bell (Harold I.) Research Fund. Established 1922, by Mrs. Ellen Foster Bell, as a memorial to her husband, Harold I. Bell, to purchase equipment and supplies for research in the field of hydraulic engineering and related subjects. Capital, $5000. Annually available, $200.

Gage (Susanna Phelps) Fund. Established 1918, by Simond Henry Gage and H. Phelps Gage, to advance knowledge of physics. Capital, $10,000. Annually available, $430. Disbursement made upon recommendation from the professors of physics at Cornell University.

Heckscher Research Foundation. Established 1920, by August Heckscher, to promote research at Cornell University. Capital, $500,000. A variable amount is annually available for grants to members of the Faculty of Cornell University.

Williams (Henry Shaler) Memorial Fund. Established 1929, by a group of contributors, to foster scientific study and research in geology. Original amount, $2500. Present amount, $14,754. Annually available, $472. The income is used to help support a geological summer camp in Pennsylvania, where students work under the direction of Professor C. M. Nevin.

CORNELL UNIVERSITY MEDICAL COLLEGE, New York, N. Y.

American Medical Association Grant. Granted November, 1933, for therapeutic research in clinical studies of the disorders of the ductless glands. $250 a year.

Animal Research Farm. A yearly grant of $25,000 (originally made by the General Education Board in 1926 and now sponsored by the Rockefeller Foundation) is made for studies in experimental anatomy, particularly inheritance and growth in relation to internal secretions.

Bernheim Fund. The first gift by Dr. Alice R. Bernheim was in July, 1932, for research in peripheral vascular diseases. $3300.

Epidemiology Studies. A grant was made in 1933 from the Rockefeller Foundation for studies in the epidemiology of tuberculosis. $3550 a year.

Experimental Biochemistry. The original grant was made in 1910 for experiments in biological products. $8200 a year. (Formerly the Johnston Livingston Fund).

Given Surgical Fund. Gifts have been made since 1925 by Mrs. Irene Heinz Given for teaching and research in surgery. $5425 a year.

Leucemia Lymphoma Fund. Transferred to Cornell University Medical College June, 1932. Grant received through Dr. Eugene L. Opie for leucemia research to be expended over a period of years. Budget 1933-34, $15,000.

Macy Foundation Transfusion Research Fund. Established by the Macy Foundation in February, 1934, to study the effect of repeated transfusions on the process of aging. $1000.

Macy Surgical Fund. A grant was made by the Josiah Macy Jr. Foundation in June, 1933 for experimental surgical research. $1500 a year.

National Research Council. Grants were made in 1933 as follows: for research in goitre-producing substance found in cabbages, $292; for senile studies in the prostate gland, $230.

Pediatric Fund. Established 1925, by Mr. H. K. McHarg, for research in children's diseases. $6000 a year.

Peters Fund. A gift was received in 1930, under the will of Mary L. Walker Peters in memory of her husband, Charles Grenville Peters. The income is to be used for cancer research. None of such income is to be used for the construction of buildings. $1075 a year.

Research in Public Health. An anonymous gift in 1934, for researches in public health. $200 a year.

Sackett (Dr. Solon P.) Fund. Established 1930, by Henry W. Sackett, to be used by the faculty of medicine for research in the medical college. Original amount, $12,000. Annually available, $480.

Sage (Sarah Manning) Research Fund. Established 1915, for the advancement of medical science by the prosecution of research at Ithaca. Allocated to the professors of the College of Medicine. Original amount, $50,000. Present amount, $55,000. Annually available, $2200.

Sage Tuberculosis Research Fund. Grants since 1927 for research in metabolism of tubercle bacilli and tuberculous tissue. Work is carried on at the Russell Sage Institute of Pathology, but administered through Cornell University Medical College. $2500 a year.

Sex Research Fund. Grants have been made since 1923 by the National Research Council, Committee on Sex Research, for studies in the physiology and morphology of sex in mammalia. $3000 a year.

Surgery Transfusion Fund. Gifts have been made since 1925 by Dr. John A. Hartwell, Dr. Harold E. Santee and Mrs. Irene Heinz Given, for blood transfusion for needy patients in Bellevue Hospital, New York City and for scientific research. $2354 a year.

Thompson Fund. Gift of Mrs. Carlos de Heredia, in 1929, to promote interest in the study or teaching of industrial diseases. $225 a year.

Tuberculosis Fund. Grants have been made since 1926 by the National Tuberculosis Association to gain more knowledge in problems presented by tuberculosis, to study the chemistry of the living cells of the animal body that are most active in response to this infection, the biology of tubercle bacilli and the relation of the cells of blood in destructive action on the tubercle bacillus. $7250 a year.

Tuberculosis Research Fund. Grant made by the Rockefeller Foundation for tuberculosis studies. $12,000 a year.

CROP PROTECTION INSTITUTE, Care of the National Research Council, 2101 Constitution Ave., Washington, D. C.

The Institute, since its organization in 1920, has undertaken projects representing total expenditures aggregating more than $500,000. A substantial part of this money was provided by different industrial organizations for special research investigations and does not constitute a permanent fund. For the year ending June 30, 1933, the total receipts were approximately $50,000. The Institute in December, 1933, was conducting seventeen major projects and four exploratory projects.

DUKE UNIVERSITY, Durham, N. C.

Allotments from departmental budgets. In 1932-33, $400 was allotted from the budget of the forestry department. In 1933-34, $7900 was allotted from departmental budgets of the departments of the school of medicine.

Allotments from laboratory budgets. In 1932-33 allotments were made from the laboratory budget of the department of chemistry of $1200 and $500 from that of the department of botany. In 1933-34, $1025 was allotted from the laboratory budget of the department of physics and $1270 from that of the department of zoology.

Industrial Research Fund. Established 1933, by Liggett and Myers Tobacco Company, for the investigation of fertilizer and, growing problems and diseases of tobacco for the benefit of the tobacco industry as a whole. Annually available, $12,000.

Lederle Laboratories Grants. The Lederle Laboratories, Inc. have made the following grants in 1933-34 to the Medical School: $1200 for investigation of the purification and concentration of diphtheria antitoxin; $500 for studies of pellagra.

ELECTROCHEMICAL SOCIETY, INC., THE, Colin G. Fink, Secretary, Columbia University, New York, N. Y.

Acheson (Dr. Edward Goodrich) Fund. Dr. Acheson, at the 54th Convention of the Society in 1928 established a fund of $25,000 as the basis of an award every second year of a gold medal and a prize of $1000 to anyone who has made a distinguished contribution to any of the branches fostered by the Society.

Prize of $100. Established 1928, to be awarded annually for the best paper published in its Transactions by a young student or graduate under twenty-seven years of age.

Roeber Research Fund. Established September, 1933 in honor of Dr. E. F. Roeber, one of the foremost pioneers in American electrochemistry, by his friends. Starting with 1935 there will be available each year approximately $50 to be assigned to a research student in electrochemistry for the purchase of special apparatus or supplies. The student is not to be more than 28 years old, and must be a student in electrochemistry; he shall have been a member of the Electrochemical Society for at least one year at the time of his application for financial assistance. The selection of the candidate will be by a committee of three university professors; the research for which assistance is given shall be reported and submitted to the Electrochemical Society. There shall be only one candidate per year; the money advanced is to be considered as a loan to be returned to the Society and added to the principal sum of the Roeber Research Fund at the end of five or ten years. Requests for such assistance should be addressed to the Chairman of the Fund or to the Secretary of the Society.

ENGINEERING FOUNDATION, 29 West 39th St., New York, N. Y.

The following capital funds are administered separately by United Engineering Trustees, Inc., but the income is used as one fund by the Engineering Foundation Board, excepting the portion designated for the library. The Foundation's income from the three funds is $35,000.

Engineering Foundation. Established 1914, by the American Societies of Civil, Mining and Metallurgical, Mechanical, and Electrical Engineers on the basis of a gift of $200,000 by Ambrose Swasey, for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind. Additions to the endowment have been made by Mr. Swasey and others from time to time. Present amount, $780,000.

Adams (Edward Dean) Fund. Established 1927, by Edward Dean Adams, for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind. Present amount, $100,000. Income divided equally between Engineering Foundation and Engineering Societies Library.

Towne (Henry R.) Engineering Fund. Established 1925, by Henry R. Towne, for the furtherance of research in science and engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind. Present amount, $50,000.

EUGENICS RESEARCH ASSOCIATION, Cold Spring Harbor, Long Island, N. Y.

From time to time small sums have come to the Subsidy Committee for use in advancing some particular study, and the Association appropriates sums of money from time to time from its current income to encourage research in eugenics and particularly to aid beginners in investigation to bring their firsthand studies to a successful termination. During the current year there will be available $4000 for prizes for researches on the " probability of commitment for a mental disorder of any kind, based on the individual's family history."

FENGER MEMORIAL FUND. *See* John Rockefeller McCormick Institute for Infectious Diseases.

FRANKLIN INSTITUTE, THE, 20th St. and Parkway, Philadelphia, Pa.

Bartol (Henry W.) Research Foundation. Established 1918, by Henry W. Bartol, for carrying on research in the physical sciences, especially electricity, and in scientific problems growing out of industry. Original amount, $1,200,000. Present amount, $1,700,000. Annually available, $92,000.

Boyden Premium. Established by Uriah A. Boyden of Boston, Mass., to be awarded to any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity. Amount of award, $1000. An award, made during the year 1907, covered the solution of the problem so far as the transmission of the visible and ultra-violet rays is concerned. The balance of the award will be made to such person as shall demonstrate whether or not the infra-red rays are or are not transmitted with the same velocity as the other rays.

Clark (Walton) Medal (Gold). Established in 1926, to be awarded to the author of the most notable advance in knowledge, or improvement in apparatus, or in method, concerning the science or the art of gas manufacture, or distribution or utilization in the production of illumination, or of heat, or of power.

Cresson (Ellicott) Medal (Gold). Established 1848, to be awarded for discovery or original research adding to the sum of human knowledge irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship. Original amount, $1000.

Franklin Medal (Gold). Established 1914, by Samuel Insull, Esq., to be awarded annually to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and The Arts, have done most to advance a knowledge of physical science or its applications.

Henderson (George R.) Medal (Gold). Awarded for meritorious inventions or discoveries in the field of railway engineering.

Levy (Louis E.) Medal (Gold). Awarded to the author of a paper of especial merit, published in the Journal of The Franklin Institute, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

Longstreth (Edward) Medal (Silver). Established 1890, to be awarded for the encouragement of invention, and in recognition of meritorious work in science and the industrial arts. In the event of an accumulation of the fund for medals beyond the sum of $100 it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance. Amount, $2000. (In March, 1913, Charles Longstreth, the son of the above-named Edward Longstreth, deposited with The Franklin Institute the further sum of $1000 to be added to the original fund to be kept with it in trust in perpetuity, the interest to be used as is the interest of the original fund, making the total sum as indicated above.)

Potts (Howard N.) Medal (Gold). Awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles.

Wetherill (John Price) Medal (Silver). Awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

FRASCH (HERMAN) FOUNDATION, U. S. Trust Co. of New York, Trustee, 45 Wall St., New York, N. Y.

Frasch (Herman) Foundation for Chemical Research. Established 1927, by will of Elizabeth Blee Frasch, widow of Herman Frasch, for research in the field of agricultural chemistry with the object of attaining results which shall be of practical benefit to the agricultural development of the United States. The income is to be paid to one or more incorporated institutions in the United States to be selected by the trustee after advising with the American Chemical Society. Payment of such income to the institutions so selected shall continue for five years, when the work done by the institutions with funds received from the Foundation is to be examined by the American Chemical Society and a report made to the trustee whether in the opinion of the Society satisfactory progress has been made.

FRITZ (JOHN) MEDAL FUND CORPORATION, 29 West 39th St., New York, N. Y.

Fritz (John) Medal Fund. Established 1902, by friends of John Fritz, for an annual award of a medal for notable scientific or industrial achievement. Original amount, $3500. Present amount, $3500. Annually available, $122. The John Fritz Medal Board of Award represents the four American Societies of Civil, Mining and Metallurgical, Mechanical, and Electrical Engineers. Roy V. Wright, Honorary Secretary; Alfred D. Flinn, Assistant Secretary.

GENERAL ELECTRIC COMPANY, Schenectady, N. Y.

Coffin (Charles A.) Foundation. Established 1922, by the Company in appreciation of the achievements of the late Charles A. Coffin, for encouraging and rewarding services in the electrical field by giving prizes to its employees, recognition to lighting, power and electric railway companies for improvement in service to the public, and fellowships to graduate students and funds for research work at technical schools and colleges. Original amount, $400,000. Annually available, approximately $20,000.

GENETIC FOUNDATION, Henry W. Toll, Secretary, 730 Equitable Bldg., Denver, Colo.

Established 1921, incorporated 1922, to gather and to disseminate information concerning mutations and other principles of heredity, from the standpoint of the improvement of the human race. The Foundation is a small one and its income is used to finance lectures and prize essays.

GEOGRAPHIC SOCIETY OF CHICAGO, 7 South Dearborn St., Chicago, Ill.

Culver (Helen) Gold Medal Fund. Established 1907, by Helen Culver, to be awarded in recognition of valuable contributions to the science of geography. Present amount, $2000. Awarded on the unanimous vote of the Directors.

Geographic Society of Chicago Gold Medal. Occasionally awarded.

GEOGRAPHICAL SOCIETY OF PHILADELPHIA, 400 Witherspoon Bldg., Philadelphia, Pa.

Kane (Elisha Kent) Medal. Established 1893, for important geographical exploration or research.

GEOLOGICAL SOCIETY OF AMERICA, Inc., 419 West 117th St., New York, N. Y.

Penrose Bequest. Established 1931, by will of Dr. Richard Alexander Fullerton Penrose, Jr., the income to be used for the promotion of the science of geology in North America. Original amount, $3,872,305.

Present amount, $3,930,133. Annually available, the income only. Applications for grants in aid of research may be filed at any time with the office of the Society or the Committee on Projects. All projects are first considered by the Committee on Projects, which is advisory to the Council of the Society. Final decision rests with the Council, which meets in April, October and December of each year.

Penrose Medal. Established 1927, by Dr. R. A. F. Penrose, Jr., in recognition of outstanding original contributions or achievements which mark a decided advance in the science of geology. Original amount, $5000. Annually available, interest only. Selection rests with special committee and the Council of the Society. There is no special time for conferring the medal.

GEORGIA, UNIVERSITY OF, Athens, Ga.

Smith (Martin Reynolds) Memorial Fund. Established 1924, by J. Warren Smith, to encourage original research work. Original amount, $2000. The annual income of $85 is used to provide honorarium for a graduate of the University whose work in original research is adjudged worthy by the determining committee. For detailed information write to Alfred Scott, Head Professor of Chemistry, University of Georgia, Athens, Georgia.

GRINNELL COLLEGE, Grinnell, Iowa.

Hendrixson (Walter Scott) Memorial Fund. Established 1925, in memory of Professor Hendrixson, to promote the spirit of research in pure science and mathematics in the faculty of Grinnell College. Present amount, approximately, $9000. Annually available, about $450. Income may be used for purchasing books, research material, remuneration of research assistants, expense of drawings or cost of publication of research papers. The only restriction is that the work must be done by or under the direction of members of the faculty of Grinnell College.

GRUNOW (LOIS) MEMORIAL CLINIC, INC. FOR SCIENTIFIC RESEARCH, Phoenix, Ariz.

Grunow (Lois) Memorial Clinic, Inc. Established 1930, by William C. Grunow of Chicago, Ill., for scientific research. Capital, $300,000. A tentative estimate of $15,000 a year should be available for research in clinical medicine and biological chemistry.

GUGGENHEIM (DANIEL) MEDAL FUND, INC., 29 West 39th St., New York, N. Y.

Established 1927, to award a medal from time to time, to a person in recognition of some notable achievement performed by him which shall tend to the advancement of aeronautics. The Corporation administering the fund has eight members, divided into four classes of two members each. One member of each class must be a member of the American Society of Mechanical Engineers and the other a member of the Society of Automotive Engineers, as long as these societies exist. The meeting to consider the award is held on the first Wednesday of May.

HARRISBURG (PA.) ACADEMY OF MEDICINE, Harrisburg, Pa.

Seibert (William) Memorial Prize. Awarded every two years to a member of the Academy who has done notable work. $500.

HARVARD UNIVERSITY, Cambridge, Mass.

The University has more than a thousand funds devoted to research, but as no distinction is made between teaching and research funds, only a partial list of the more important are given here.

HARVARD COLLEGE

Bowdoin Prizes. Established 1791, for dissertations in any special field of learning. Two prizes are for dissertations in science. Present amount, $57,272. Annually available, $2204.

Coolidge Fund. Established 1901, for physical research. Original amount, $57,500. Present amount, $41,159. Annually available, $1584.

Dane (Ernest B.) Fund. Established 1912, for research in physics. (Only part of fund available for research). Present amount, $55,117. Annually available, $2122.

Du Pont Fund. For research in chemistry. Present amount, $133,792. Income, $5150.

Hodgson (Richard) Memorial Fund. Established 1912, for psychical research. Present amount, $25,668.

Lovering (Joseph) Fund. Established 1891, for the promotion of original research at the Jefferson Physical Laboratory. Original amount, $7720. Present amount, $8809. Annually available, $339.

Milton (William F.) Fund. Established by William F. Milton, for a suitable library building, but if not needed for that, to be used to defray the expenses of any special investigation of a medical, geographical, historical or scientific nature which the University may desire to make or prosecute in the interests of or for promoting the physical and material welfare and prosperity of the human race, or to assist in the discovery and perfecting of any special means of alleviating or curing human disease, or to investigate and determine the value or importance of any discovery or invention, or for any other special or temporary object of the nature above stated. The provisional arrangement which the Corporation has made for its immediate use is to aid members of the instructing or scientific or administrative staff of the University in investigation. Present amount, $1,208,849.

Shaler Memorial Fund. Established 1907, for original research in geology in the broadest sense, including paleontology, mineralogy, economic geology, etc. Present amount, $43,117.

Warren (Cyrus M.) Fund. Established 1893, for the promotion of chemical research or the advancement of chemical science. Original amount, $4500. Present amount, $13,967. Annually available, $537.

ARNOLD ARBORETUM

Bradley (William L.) Fund. Established 1897, for scientific investigation to increase the knowledge of trees. Original amount, $20,000. Annually available, $891.

CANCER COMMISSION

Coolidge (Jefferson) Fund. Established 1915, for cancer research. Present amount, $2200. Annually available, $84.

Croft (Caroline Brewer) Fund. Established 1899, for researches and investigations in some effectual remedy or means of cure for cancer, consumption or other diseases generally supposed to be incurable. Cancer to receive preference. Original amount, $92,025. Annually available, $3897.

Mills (Elizabeth Worcester) Fund. Income to be devoted to the investigation of the origin and cure of cancer. Present amount, $224,984. Annually available, $8661.

Mosely (Julia M.) Fund. Income to be used for work of the Cancer Commission. Present amount, $24,757. Annually available, $953.

HARVARD FOREST

Harvard Forest Endowment Fund. Established 1930 by many donors, for the endowment of Harvard Forest. Present amount, $199,638. Annually available, $7686.

MEDICAL SCHOOL

Austin (Edward) Fund. Established 1899, for research in the bacteriological laboratory. Original amount, $10,000. Present amount, $12,763. Annually available, $491.

Bell (Richard Dana) Fund. Established 1926, for the benefit of the Department of Biological Chemistry. Original amount, $100,000. Present amount, $137,938. Annually available, $5310.

Bowditch Fund. Established 1889, for the promotion of original investigations in the physiological laboratory of the Harvard Medical School. Original amount, $6000. Present amount, $11,101. Annually available, $427.

Boylston Prize and Medal. Established 1803, for the best essay on results of research in medicine. Triennially available, $500. Competition open to all.

Brinckerhoff Fund. Established 1911, the income to be used under the direction of the Shattuck Professor of Pathological Anatomy for the promotion of medical knowledge. Original amount, $5000. Present amount, $5691. Annually available, $219.

Burrell (Herbert L.) Fund. Established 1914, to further the art of science and surgery. Present amount, $7042. Annually available, $271.

Colburn Fund. Established 1919, for research in tuberculosis. Original amount, $97,052. Present amount, $134,674. Annually available, $5184.

De Lamar (Joseph) Fund. Established 1920, for the study and teaching of the origin and cause of disease and its prevention and for the study and teaching of dietetics. Original amount, $5,143,732.

Dwight (Thomas) Memorial. Established 1912, for anatomical research in the Medical School. Original amount, $12,971. Present amount, $20,165. Annually available, $776.

Farnsworth Memorial (Harvard Endowment). Established 1920, for medical research. Original amount, $8540. Present amount, $14,598. Annually available, $562.

Farrington (Charles F.) Fund. Established 1909, for investigations that may advance the knowledge of infectious or communicable or kindred diseases. Original amount, $50,000. Present amount, $62,307. Annually available, $2398.

Flattery Medal. Established 1918, for the person who makes a discovery in any branch of science resulting in greatest good to humanity in the prevention of disease or preservation of health in the broadest sense. Original amount, $7500. Competition open to all.

Flattery Research Fund. Established 1915, for cancer research. Present amount, $85,039. Annually available, $3436.

General Education Board Ophthalmology Fund. Established 1926, for research in the Howe Laboratory of Ophthalmology. Original amount, $175,000. Present amount, $213,740. Annually available, $8229.

Greenough Fund. Established 1901, for surgical research. Original amount, $2000. Present amount, $6619. Annually available, $254.

Harvard Infantile Paralysis Commission. Established 1923, for research on infantile paralysis. Balance of gift, $18,572.

Henry (George E.) Bequest. Established 1925, for determination of cause and treatment of infantile paralysis. Original amount, $50,000. Present amount, $57,460. Annually available, $2212.

Howe Laboratory of Ophthalmology Research Fund. Established 1926, by Lucien Howe, M. D., for research in ophthalmology. Present amount, $287,458. Annually available, $4496.

Massachusetts General Hospital Asthma Fund. Established 1926, for research on asthma. Balance of gift, $5271.

Massachusetts General Hospital Special Fund. Established 1921, for research in medicine at the Hospital. Balance of gift, $911.

Proctor Fund. Established 1903, for promoting the study of chronic diseases. Original amount, $100,136. Present amount, $120,577. Annually available, $4642.

Richardson (Maurice Howe) Fund. Established 1915, the income to be devoted to the purposes of the Medical School and, where possible, to develop the work of the Department of Surgery. Original amount, $3175. Present amount, $5063. Annually available, $194.

Surgical Laboratory Fund. Established 1897, for research in surgery. Original amount, $5000. Present amount, $5622. Annually available, $216.

Underhill (Zoe D.) Fund. Established 1912, for research in neuropathology. Present amount, $11,084. Annually available, $426.

Ward (General Artemus) Fund. Established 1926, for research in Howe Laboratory of Ophthalmology. Original amount, $75,000. Present amount, $112,733. Annually available, $4340.

Wellington (William W.) Memorial Research Fund. Established 1926, for research concerning the etiology and therapeutics of diseases of man.

Wright (William J. and Georgiana B.) Fund. Established 1920, for medical research and the advancement of the medical and surgical sciences. Original amount, $413,840. Present amount, $522,821. Annually available, $15,041.

Wyman (Morrill) Medical Research Fund. Established 1915, for investigation concerning origin, results, prevention and treatment of disease. Present amount, $194,301. Annually available, $7480.

A gift for investigation of infantile paralysis in the department of preventive medicine and hygiene was established in 1910. Present amount, $3874.

A gift for research in the department of preventive medicine and hygiene has a present amount of $1063.

OBSERVATORY

Advancement of Astronomical Science Fund. Established 1901, for aiding work of astronomers at Harvard Observatory. Present amount, $4693.

Advancement of Astronomical Science Fund. Established 1902, for aiding astronomers at Harvard Observatory. Annually available, $556.

Paine (Robert Treat) Fund. Established 1886, for rewards by medals or otherwise for discovery of new comets, planets or for essays on valuable subjects. Present amount, $301,325. Annually available, $11,601.

Pickering (Edward C.) Memorial. Established 1931, by Harvard University and the American Association of Variable Star Observers, for research in the study of variable stars. Original amount, $100,000. Annually available, $3859.

PEABODY MUSEUM

Hemenway (Mary) Fund. Established 1910, for archaeological research, acquisition of specimens or salaries. Original amount, $45,000. Present amount, $49,559. Annually available, $1908.

Peabody Foundation Fund. Established 1866, for research and the diffusion of knowledge pertaining to archaeology and ethnology, and for the acquisition of and caring for collections with special reference to aboriginal American tribes. Original amount, $150,000. Present amount, $139,830. Annually available, $5383.

Sweet (Henry N.) Fund. Established 1917, for use in connection with Middle American archaeology and ethnology. Present amount, $2826. Annually available, $108.

Warren (Henry C.) Fund. Established 1899, for explorations. Original amount, $10,000. Present amount, $11,230. Annually available, $432.

Wolcott (Huntington F.) Fund. Established 1891, for the promotion of archaeology and ethnology, the purchase of specimens and for publication. Original amount, $10,000. Present amount, $22,273. Annually available, $857.

School of Public Health

Dexter Fund, for research study in the Department of Bacteriology. Present amount, $202,977. Annually available, $7814.

Expenses of Instruction and Investigation in Industrial Hygiene. Present amount, $20,200.

Melvin (James C.) Fund. Established 1918, for research in tropical medicine. Original amount, $50,000. Present amount, $62,901. Annually available, $2421.

HAWAII, UNIVERSITY OF, Honolulu, Hawaii.

Dean (Arthur Lyman) Prize for Research. Established 1927, by faculty members, to encourage research. Original amount, $700. Annually available, $50.

HAWAIIAN SUGAR PLANTERS' ASSOCIATION, Honolulu, Hawaii.

Experiment Station of the Hawaiian Sugar Planters' Association. Established 1895, for investigations and research pertaining to sugar cane agriculture and manufacture for the ultimate objects of increasing yields and reducing costs of production. Funds voted as needed from moneys subscribed by the plantations of the Association. Annual expenses have increased during the past few years from $200,000 to $400,000.

HECKSCHER INSTITUTE FOR CHILD HEALTH, Dr. I. N. Kugelmass, Director, 1060 Park Ave., New York, N. Y.

Established 1930 by the Heckscher Foundation for Children for the practice of preventive pediatrics with under-privileged children. The clinical observations are correlated with research studies in all departments of pediatrics, including dentistry. $25,000.

HELMINTHOLOGICAL SOCIETY OF WASHINGTON, E. E. Wehr, Secretary, Bureau of Animal Industry, Washington, D. C.

Ransom Memorial Fund. Established 1926, by friends, relatives and co-workers of B. H. Ransom in the field of parasitology, to encourage parasitological research, especially, in young workers, by a money prize. The prize is to be given to a worker, who has not passed his 40th birthday, for noteworthy contribution in parasitology. Original amount, $1000. Present amount, $1182. Annually available, interest at three per cent.

HIGHWAY RESEARCH BOARD, 2101 Constitution Ave., Washington, D. C.

The Highway Research Board was organized in 1920 by the National Research Council, through its Division of Engineering and Industrial Research. Special investigations of the Board are financed by contributions from interested organizations.

HOROLOGICAL INSTITUTE OF AMERICA, Ralph E. Gould, Corresponding Secretary, Bureau of Standards, Washington, D. C.

Medals are awarded from time to time to stimulate interest in better workmanship and the initiative and skill used in the creation of new tools.

HUMAN BETTERMENT FOUNDATION, Paul Popenoe, Secretary, Suite 321, Pacific Southwest Bldg., Pasadena, Calif.

Human Betterment Foundation. Established 1929, by E. S. Gosney, for conservative, preventive work for humanity. Its goal is the constructive, practical advancement and betterment of human life, character and citizenship. No funds available for outside grants at present, as they are all budgetted for the continuation of studies of eugenic sterilization.

ILLINOIS, UNIVERSITY OF, Urbana, Ill.

Agricultural Adjustment Study. Established 1933, by Brookings Institution for the study of the organization and operation of the Federal Agricultural Adjustment Act during the time the act is in operation. Available, $750.

Agricultural Experiment Station. Established 1888, for research in agriculture. Annually available, $475,242.

American Medical Association Funds.

Irradiated Ergosterol. Established, 1930. Available, $200.
Study of Hemophilia. Established, 1934. Available, $300.
Therapeutic Research. Established, 1933. Available, $375.
Ultra-violet Research. Established, 1933. Available, $375.

Animal Hearing Research Fund. Established 1931, by American Otological Society, for research on hearing of animals. Available, $3150.

Beaumont (William) Prize. Established 1927 by Dr. Frank Smithies, to promote study of diseases of alimentary tract. Present amount, $2000. Annually available, $100. The prize is administered by a committee appointed by the Dean of the College of Medicine and awarded to the best piece of research work presented by any member of the College or student body on gastro-intestinal disease.

Concrete Arches Investigation. Established 1927, by American Society of Civil Engineers. Available, $900.

Cooperative Investigation of Brick Masonry. Established 1933, by Common Brick Manufacturing Association of America. Available, $125.

Cooperative Investigation of Cast Iron Pipe. Established 1927, by Sectional Committee of American Engineering Standards Committee. Available, $400.

Cooperative Investigation of Effect of High Temperature on Skimmed Milk. Established 1933, by American Dry Milk Institute. Available, $1300.

Cooperative Investigation of Heating and Ventilating Research. Established 1931, by American Society of Hearing and Ventilating Engineers. Available, $3000.

Cooperative Investigation of Methods of Cleaning Coal. Established 1933, by Franklin County Coal Company. Available, $225.

Cooperative Investigation of Potash Effect on Crop Production. Established 1929, by N. V. Potash Export My. of Amsterdam, Holland. Available, $425.

Cooperative Investigation of Rails. Established 1931, by American Railway Association and Illinois Steel Company. Available, $43,000.

Cooperative Investigation of Reinforced Concrete Frames. Established 1933, by Portland Cement Association. Available, $4000.

Cooperative Investigation of Scale Studies. Established 1933, by National Aluminate Corporation. Available, $3950.

Cooperative Investigation of Sound Absorption of Materials. Established 1932, by United States Gypsum Company. Available, $1200.

Cooperative Investigation of Toxin Formation in Canned Meat. Established 1929, by Institute of American Meat Packers. Available, $400.

Cooperative Investigation of Transmission Lines. Established 1931, by Super Power Company of Illinois. Available, $746.

Cuprous Cyanide Research Fund. Established 1933, by E. I. duPont de Nemours and Company for research on the physiological effects of cuprous cyanide. Available, $1500.

Dairy Husbandry Research Assistantship. Established 1932, by Dairy and Ice Cream Machinery and Supplies Association. Available, $850.

Deuss (James Burkett) Memorial Prize. Established 1931, by Dr. and Mrs. Hugo O. Deuss, to promote study in the field of allergy. $100 available every other year. Awarded to a registered student or faculty member of the College of Medicine presenting the best thesis on allergy.

Engineering Experiment Station. Established 1903, for research in engineering. Annually available, $67,479.

Furnace Research Fund. Established 1918, by National Warm Air Heating Association. Available, $2600.

General Graduate Research Funds. Established 1892, for research in all departments including scientific departments. Annually available, $5000.

Graduate Special Research Fund. Established 1927, for further investigation of illinium by Dr. Hopkins. Available, $1000.

Humidity Determination Fund. Established 1933, by du Pont Rayon Company, for determination of moisture in colloidal materials and the determination of relative humidities. Available, $250.

Lubrication Research Fund. Established 1933, by Continental Oil Company. Available, $750.

Marketability of Fluid Milk Fund. Established 1929, by International Association of Milk Dealers. Available, $125.

Mead Johnson and Company Funds.

Dermatitis Research Fund. Established 1932. Available, $125.

Irradiated Ergosterol Research Fund. Established 1929. Available, $3400.

National Research Council Funds.

Amino Acids Research Fund. Established 1930. Available, $125.
Cardiodynamics Research Fund. Established 1933. Available, $150.
Hormones and Fatigue. Established 1933. Available, $175.
Magnetic Moment of Hydrogen. Established 1933. Available, $141.
Radiation Effect on Pollen. Established 1929. Available, $1025.

Public Utilities Economics Research Fund. Established 1926, by a committee representing certain Public Utilities Companies for research in the form of fellowships or traveling expenses. Available, $1496.

Research Assistantship on X-ray Materials used in Manufacturing Surgical Supplies. Established 1930, by Bauer and Black. Available, $600.

Sanitary Research Fund. Established 1925, by Chemical Foundation. Available, $725.

Serum Proteins Fund. Established 1928, by Eli Lilly and Company. Available, $1200.

Skin Hygiene Fund. Established 1932, by International Cellucotton Products Company, for research on hygienic care of the skin. Available, $3125.

Standard Brands Funds.

Antiseptic Properties of the Skin. Established 1930. Available, $5850.

Yeast Effect on Digestive Tract. Established 1929. Available, $2275.

Sweet Corn Investigation. Established 1923, by Illinois Canners Association. Available, $175.

Tests on Welded Joints Fund. Established 1933, by Hollup Corporation. Available, $500.

Thompson (Elizabeth) Science Fund. Established 1933, by Elizabeth Thompson, for feed and care of test animals. Available, $250.

Utilities Research Commission Funds.

Solubility of Boiler Waters. Established 1930. Available, $3675.
Stack Gases. Established 1928. Available, $4275.
Stretching of Lead Sheaths. Established 1928. Available, $1350.
Testing High Voltage Cables. Established 1926. Available, $275.
X-ray Study of Insulating Oils. Established 1933. Available, $500.

INDIANA ACADEMY OF SCIENCE, Care of State Librarian, Indianapolis, Ind.

Academy Foundation. Established 1919, to promote research. Present amount, $4500. Not available for use at present.

INDIANA UNIVERSITY, Bloomington, Ind.

An annual appropriation is made by the Trustees of the University from the general budget for research projects approved by the University. Available 1933-34, $5000.

Huesmann Fund. Established 1927, by James Whitcomb Riley Society in memory of Louis C. Huesmann, for research in diseases of children. Original amount, $54,000. Present amount, $65,000. Annually available, $3000.

Johnson Fund. Established 1928, by Helen M. Eichrodt in memory of Albert D. and Belle E. Johnson, for research on diseases of children in connection with the James Whitcomb Riley Hospital for Children. Present amount, $5000. Income annually, $250.

Landon Research Fund. Established 1930, by Jessie Spalding Landon in memory of Hugh McK. Landon, for research and educational work in subjects relating to the work of James Whitcomb Riley Memorial Association. Present amount, $200,000. Annually available, $8000.

Lilly Research Fund. Established by Eli Lilly and Co., for research at the Medical School. First grant of $1200 annually for four years was made in 1925; second grant of $5000 annually for three years was made in 1929; third grant of $5000 annually for three years was made in 1932.

Waterman Research Fund. Established 1915, by Dr. Luther Dana Waterman, to endow the Waterman Institute for Scientific Research. Original amount, $71,800. Present amount, $88,800. Annually available, $3000.

INSTITUTE OF AMERICAN MEAT PACKERS, Chicago, Ill.

Department of Scientific Research of the Institute carries a budget of about $23,000 for research. The work is done in the Research Laboratory of the Institute, founded by Thomas E. Wilson, at the University of Chicago.

INSTITUTE OF FOREST GENETICS, Placerville, Calif.

Carnegie Institution of Washington Grants. Grants of $4900 were made in 1933 to the Institute to be used insofar as possible for specified lines of investigation.

Eddy (James G.) Grants. Established 1925, by James G. Eddy, for the establishment and operation of the Institute. Up to 1931 about $25,000 a year was available; less than half that amount since then.

INSTITUTE OF MEDICINE OF CHICAGO, 122 South Michigan Blvd., Chicago, Ill.

Capps (Joseph A.) Prize. Established 1930, by an anonymous donor, to promote meritorious medical research. Original amount, $10,000. Annually available, approximately $500. Research must be completed within two years after graduation by a graduate of a medical school in Chicago. Manuscripts should be submitted not later than December 31st to the Secretary of the Institute of Medicine. In case none of the investigations submitted are deemed worthy of the prize, the income for that year is to be used for a lectureship to be known as the Joseph A. Capps Lecture in Medicine.

INSTITUTE OF RADIO ENGINEERS, 33 West 39th St., New York, N. Y.

Liebmann (Morris) Memorial Prize. Established by Emil J. Simon to perpetuate the memory of the late Colonel Morris N. Liebmann. The award consists of $500, which is the annual income of the gift of $10,000. It is made to that member of the Institute who, in the opinion of the special committee appointed annually by the Board of Directors, shall have made the most important contribution to the radio art during the preceding calendar year.

Medal of Honor. Established 1918. A gold medal suitably engraved is awarded to that person who has made public the greatest advance in the science or art of radio communication, regardless of the time of performance or publication of the work on which the award is based. The advance may be an unpatented or patented invention which has been completely and adequately described in a scientific or engineering publication of recognized standing, and must be in actual operation, preference being given to widely used and useful inventions. It may also be a scientific analysis or explanation of hitherto unexplained phenomena of distinct importance to the radio art, though the application thereof need not be immediate, preference being given analyses directly applicable in the art. Publication in this case also must be in full and approved form. It may further be a new system of traffic regulation or control; a new system of administration of radio companies or of service of steamship, railroad or other companies; a legislative program beneficial to the radio art, or any portion of the operating or regulating features of the art. It must be described publicly in clear and approved form and must, in general, be actually adopted in practice.

INTERNATIONAL ACETYLENE ASSOCIATION,.30 East 42nd St., New York, N. Y.

Morehead Medal. Established 1922, by the Honorable John Motley Morehead, for presentation to the person or persons who, in the judgment of the officers and Board of Directors of the Association have done most to advance the industry or the art of producing or utilizing calcium carbide or its derivatives or have submitted to the Association the best paper or delivered before the Association or a Committee thereof the best address on practical improvements in the art. The award is a gold medal, costing approximately $125, and a certificate engrossed on parchment, costing approximately $25. These are awarded annually.

INTERNATIONAL CANCER RESEARCH FOUNDATION, Suite 1710, 1616 Walnut St., Philadelphia, Pa.

International Cancer Research Foundation. Established June 8, 1932, by W. H. Donner, to further research into the causes, prevention, control, treatment and cure of those diseases grouped under the head of malignant tumors. Original amount, $2,000,000. Annually available, $135,000 (1933). Application should be filed with the Secretary. Any qualified investigator in any country is eligible for a grant from this fund, under conditions as set forth in the booklets of the Foundation.

INTER-STATE POSTGRADUATE MEDICAL ASSOCIATION OF NORTH AMERICA, Dr. Henry G. Langworthy, Director, 394 West 10th St., Dubuque, Iowa.

Schneider (Joseph) Endowment. Established 1924, by Dr. Joseph Schneider of Milwaukee, Wis., to foster the development of research work and reports of scientific progress, with particular reference to constitutional diseases and their effect upon the eye and optic nerve. The results of such research work are presented by invitation at the annual International Medical Assembly of the Association, published in the organization's yearly Proceedings and disseminated in pamphlet form by the Director.

IOWA, STATE UNIVERSITY OF, Iowa City, Iowa.

Botany Research Fund. Established 1932, by the Fish and Game Commission and the Board of Conservation. For research in blue-green algae. Annually available, $3052.

Corn Industries Research Foundation Fund. Established 1933, by the Foundation for research in the study of certain clinical properties of dextrose. Annually available, $500.

Fleischmann Yeast Company Fund. Established 1933 for research in the nutritive value of yeast in bread. Annually available, $2200.

Hydraulics Research Fund. Established 1932, through gifts from state agencies for research in stream gaging. Annually available, $3096.

Laura Spelman Rockefeller Fund. Established 1928 for research in child welfare work. Original amount, $818,000. Present amount, $101,000.

Lever Brothers Company Fund. Established 1932 for research in anti-oxygens. Annually available, $3246.

Mead Johnson Company Fund. Established 1929 for research in infant metabolism. Annually available, $7200.

National Live Stock and Meat Board Fund. Established 1931, through the National Research Council, for research in liver proteins. Annually available, $750.

Physiology Research Fund. Established 1926, by the Rockefeller Foundation, for research in physiology of the brain. Original amount, $30,000. Present amount, $2000.

Research in Problems of Sex. Established 1926, by the National Research Council. Annually available, $4500.

In addition to the above, the University carries on extensive research, estimated at $150,000.

IOWA ACADEMY OF SCIENCE, Des Moines, Iowa.

A fund was established in 1926 by the Academy to encourage research. Annually available, about $150. Grants may be made for carrying on scientific projects in Iowa under the auspices of the Executive Committee of the Academy.

IOWA STATE COLLEGE, Ames, Iowa.

During the current year (1933-34) the following funds are being used directly for research. They do not include buildings or certain items of equipment:

Agricultural Experiment Station. Appropriated by State. Exclusive of federal funds, $192,562.75.

Cast Iron Pipe Fund. Established 1927, by Sectional Committee on Specifications of Cast Iron Pipe, A. S. A., Burlington, Ala., to determine the strength of cast iron pipe under various conditions of loading. Present amount, $1000.

Chemical Foundation Fund. Established about 1928, by Chemical Foundation, for sewage treatment research. Present amount, $504.

Engineering Experiment Station. Appropriated by State. Amount available, $54,057.

Hanlon-Buchanan Fund. Established 1932, by Hanlon-Buchanan Company, Tulsa, Okla., for chemical engineering research (utilization of certain petroleum by-products).

Industrial Fund. From various trade associations and industries. $30,000.

Industrial Research. Appropriated by the State. Amount available, $13,738.

Rockefeller Fluid Research Fund. Established 1931, by Rockefeller Foundation, for research in the natural sciences. Total amount, $30,000.

Veterinary Medicine. Appropriated by State. Amount available, $30,354.

Wild Life Conservation Fund. Established 1932, by J. N. Darling and Iowa Fish and Game Commission. Original amount, $6000.

Other funds devoted to research amount to $100,000 annually.

Departmental funds are appropriated for research work in each department annually.

JOHN ROCKEFELLER McCORMICK INSTITUTE FOR INFECTIOUS DISEASES, 637 South Wood St., Chicago, Ill.

Fenger Memorial Fund. Established 1910, by the Fenger Memorial Association, to aid medical investigation. Original amount, $10,000. Present amount, $11,500. Annually available, $400 to $500.

Research Fund. For research in and treatment of infectious diseases. Available only within the Institution. Present amount, $1,000,000.

JOHNS HOPKINS UNIVERSITY, Baltimore, Md.

Ascariasis Studies Fund. Established 1927, by the American Child Health Association, through the Division of Medical Sciences of the National Research Council, for investigations on ascariasis and related parasitic worms in the United States, with especial reference to their effect on the health of children. Original amount, $24,850, which is to be utilized over a period of five years. Annually available: 1st year, $2450; 2nd, $3900; 3rd, $6000; 4th, $6250; 5th, $6250.

Catatonia Research Fund. Original amount, $20,000.

De Lamar (Joseph) Fund. Established 1920, for study and teaching of the cause and origin of disease and its prevention and for study and teaching of dietetics. Original amount, $5,000,000. Annually available, $250,000.

Dows (Kenneth) Tuberculosis Research Fund, for research in tuberculosis. Established 1916. Annually available, $900.

Epilepsy Medical Research Fund. Established 1916, by Miss Jessie Gillender, for research into the cause, prevention and cure of epilepsy. Capital, $150,000.

Halsted (William S.) Fund. Established 1922, by Dr. Halsted, for research in medicine, preferably surgery. Capital, $85,919.

Herter Lectureship. Established 1902, for the promotion of a more intimate knowledge of the researches of foreign investigators in the realm of medical science. Original amount $25,000. Annually available, $1000.

Hookworm Control Field Studies. Established 1921, by the International Health Division of the Rockefeller Foundation, to make investigations on the hookworm and hookworm disease. Budget made annually.

Linton (Edwin, Jr.) Fund. Established 1919, by Professor and Mrs. Edwin Linton, for research in anatomy, physiology and physiological chemistry. Capital, $5000.

Otology Research Fund. $15,000 a year for a seven-year period beginning 1932.

Physiological Optics Fund. Established in 1927, for research in physiological optics. Capital, $300,000.

Physiological Research Fund. Established 1917, for research in physiology. Capital, $10,000.

Scholl (George Barr) Fund. Established 1921, by Rev. and Mrs. George Barr Scholl, for research in medicine. Capital, $3000.

Sex Research Fund. Established by the National Research Council. Available, $2500.

Sharp and Dohme Fund. Established 1925, for research in bacteriology. $25,000, expendable over a period of years.

Sylvester Prize (medal). For research in mathematics.

Welch (William H.) Endowment Fund. Established 1914, for clinical education and research in medicine, surgery and pediatrics. Original amount, $1,273,000. Present amount, $1,623,000. Annually available, $83,000.

Williams (George Huntington) Memorial Fund. Established 1911, by Mrs. George Huntington Williams, her two sons and Miss Cornelia Williams. One-half of the income of the fund is devoted to investigation in geology and one-half used in securing lecturers on topics of widespread contemporary interest.

Wilmer (William Holland) Foundation. Established 1922, by gifts of the General Education Board and many private contributors, to establish and maintain an institution for the care, treatment and surgery of the human eye; to further research in that branch of medical science concerned with the human eye, as a tribute to the character and service to humanity of Dr. Wilmer. Original amount, $3,000,000. All funds have been turned over to Johns Hopkins University for the endowment and maintenance of the Wilmer Institute in Ophthalmology, the Wilmer Foundation Board of Trustees continuing in existence to raise further funds as needed for the Institute and to maintain a current interest in its affairs.

Young (Hugh Hampton) Research Fund. Established 1926, for experimental laboratory work and clinical research in urology. Capital, $500,000.

Departmental funds are appropriated for research work in each department annually.

KANSAS STATE AGRICULTURAL COLLEGE, Manhattan, Kans.

Engineering Experiment Station Fund. Established 1910, for research in engineering. Annually available, $17,600. The amount is from allotments of college funds, fees for commercial testing and some private donations.

State funds, including appropriations for the support of branch experiment stations, $153,500; for suppression and cure of animal diseases, $10,000; for investigations in crops and soils, $12,000.

KANSAS, UNIVERSITY OF, Lawrence, Kans.

Graduate Research Fund. Established 1920, to promote research among faculty members of the University of Kansas. Annually available (1933-34), $4000.

KETTERING FOUNDATION, O. L. Inman, Director, Antioch College, Yellow Springs, Ohio.

The fund was established in 1930 by C. F. Kettering, for the study of chlorophyll and photosynthesis. Considerable work is also done on the effect of radiation upon organic compounds. Amount available varies from year to year; 1933-34, $13,000. In the beginning the grant was estimated to cover a ten year period and to be for $200,000. Actually, as administered, it is not limited as to time but annual grants are made.

KROGER FOOD FOUNDATION, Cincinnati, Ohio.

Kroger Food Foundation. Established January 1, 1931, by Kroger Grocery and Baking Company, for studies of foods, food standards and food values and the improvement, through research, of producing, packing and preparing foods. Original amount, $1,000,000. Income annually available.

LABORATORY OF ANTHROPOLOGY, Santa Fe, N. M.

Mr. John D. Rockefeller, Jr., under date of December 7, 1928, pledged $200,000 for building and equipping the Laboratory of Anthropology, which was subsequently increased by an additional $15,000 to a total of $215,000. Through a five-year probational period, beginning January 1, 1930, he also pledged for maintenance purposes in outright cash on a diminishing basis, $20,000 each for 1930 and 1931, $15,000 for 1932, $10,000 for 1933 and $5000 for 1934, and further agreed to match dollar for dollar for identical purposes, cash contribution from other sources as follows: $10,000, for 1930 and 1931, $12,500 for 1932, $15,000 for 1933 and $17,500 for 1934. These maintenance contributions are based on a normal operating expense of $40,000 per annum. The Laboratory has claimed the major portion of these matching funds. No specific funds are yet established that are available to others for research within the Laboratory of Anthropology. On the completion of the five-year period efforts will be made for future endowment.

LONG ISLAND BIOLOGICAL ASSOCIATION, Cold Spring Harbor, N. Y.

Endowment Fund, for the support of research and instruction in biology at the Biological Laboratory. Original amount, $57,000. Annually available, $2200.

James (Dr. Walter B.) Fund. Founded 1927, by bequest of Dr. James, for support of work of the Long Island Biological Association. Capital, $5000. Annually available, $200.

Laboratory for Research in Biophysics. $45,000 annually for research in biophysics and bryology.

Matheson (William J.) Fund. Established 1931 by bequest of William J. Matheson. Original amount, $20,000. Annually available, $1000. Income employed in support of research at the Laboratory.

LOUISVILLE, UNIVERSITY OF, Louisville, Ky.

American Dental Association Research Grant. Founded 1922, for the support of dental research, the character of investigation being left to the worker. Amount varies from year to year; 1933-34, $750.

Research Grant from the University. Founded 1922, for the support of dental research, the character of investigation being left to the worker. Present amount, $2985.

MACY (JOSIAH, JR.) FOUNDATION, 565 Park Ave., New York, N. Y.

Macy (Josiah, Jr.) Foundation. Founded April 24, 1930, by Mrs. Walter G. Ladd, Far Hills, N. J., for the support of fundamental scientific investigations concerning health, sickness and relief of suffering. Present amount, $3,535,270. Annually available, approximately $180,000. Applications can be made on any date and sent to the Foundation. These are acted upon by the Executive Committee at the first meeting after the receipt of the application.

MARINE BIOLOGICAL LABORATORY, Woods Hole, Mass.

The Marine Biological Laboratory has for its primary purpose the promotion of biological research by supplying facilities to competent investigators and by the cooperation of all interested in improving the means of investigation in the biological sciences. While there is an endowment for administration and maintenance, the funds for research are those of the subscribing and cooperating institutions, who, by subscription, pay for one or more tables or rooms for research workers. The following institutions were subscribing and cooperating in 1933:

American University
Amherst College
Atlanta University
Bowdoin College
Bryn Mawr College
Chinese Educational Mission
College of St. Elizabeth
Columbia University
Commonwealth Fund
Cornell University
Cornell University Medical College
C. R. B. Foundation
De Pauw University
Duke University
General Education Board
Goucher College
Hamilton College
Harvard University
Harvard University Medical School
Hunter College
Industrial and Engineering Chemistry of the American Chemical Society
Johns Hopkins University
Johns Hopkins University Medical School
Eli Lilly and Co.
Long Island University
Memorial Hospital, New York, N. Y.
Morehouse College
Mount Holyoke College
Museum of Northern Arizona
New York State Department of Health
New York University
New York University Medical School
Oberlin College
Pennsylvania College for Women
Princeton University
Radcliffe College
Rockefeller Foundation
Rockefeller Institute for Medical Research
Rutgers University
Smith College
Sophie Newcomb College
Swarthmore College
Syracuse University
Tufts College
University of Chicago
University of Cincinnati
University of Iowa
University of Pennsylvania
University of Pennsylvania Medical School
University of Pittsburgh
University of Rochester
University of Rochester Medical School
University of Wisconsin
Vanderbilt University Medical School
Vassar College
Wabash College
Wellesley College
Wesleyan University
West Virginia State College
Wheaton College
Williams College
Wilson College
Wistar Institute of Anatomy and Biology
Yale University

MARYLAND, UNIVERSITY OF, College Park, Md.

Friedenwald (Julius) Fund. Established by Miss Eleanor S. Cohen, to be used by the Dean of the Medical School, the Professor of Medicine and Dr. Julius Friedenwald in any manner they see fit. Now being used for research in anatomy. Original amount, $12,000. Present amount, $11,500. Annually available, $605.

Hitchcock (Charles M.) Fund. Established by Elizabeth Wyche Coit, to be used for research in neuro-surgery and medicine. Original amount, $103,000. Present amount, $100,000. Annually available, $3641.

Weaver (John F. B.) Fund. Established by Dr. J. F. B. Weaver, an alumnus of the School of Medicine of the University of Maryland, to establish fellowships or a research fund. Original amount, $85,000. Present amount, $60,000. Annually available, $5444. Awarded at the discretion of the trustees of the Fund.

MASSACHUSETTS EYE AND EAR INFIRMARY, 243 Charles St., Boston, Mass.

Harvard Medical School has a fund of $500,000, the income of which is spent on the Howe Laboratory for Ophthalmic Research and the Howe Library of Ophthalmology, both of which are at the Infirmary.

MASSACHUSETTS FISH AND GAME ASSOCIATION, Museum of Comparative Zoology, Cambridge, Mass.

Marine Oil Pollution Fund. Established 1922-1923, to secure information and legislation leading to the abatement of the biological dangers of floating oil on sea.

New England Grouse Investigation, 1925-1933. Established 1925, for the investigation of the life history of the ruffed grouse, with particular reference to the cycles of scarcity which occur from time to time. There is no fixed amount, but contributions are made annually and used at the discretion of the Committee.

Stream Pollution Fund. Established 1927, for a survey and study of inland waters of the State of Massachusetts to the end that industrial pollution destructive to recreational interests may be controlled. Amount of funds depends on annual contributions of interested people.

MASSACHUSETTS GENERAL HOSPITAL, Boston, 14, Mass.

Angell (Martha B.) Fund, for the purpose of medical and surgical experimentation on animals for the saving of human lives. Present amount, $15,842. Annually available, approximately $712.

Blake (A. W.) Fund, for the care and study of nervous disease, as directed by the Chief of the Neurological Department. Present amount, $25,000. Annually available, approximately $1325.

Bourne (Emily H.) Fund. Income from $10,000 is used for the training of nurses in mental nursing and to aid in the prevention and cure of deafness.

Cabot (Samuel) Fund for Pathological Investigation. Income from $10,000 is used for salary of surgical pathologist.

Dodd (Walter J.) Memorial, for X-ray investigation. Present amount, $7962. Annually available, approximately $395.

Elliott (John W.) Fund, for investigation in science of medicine, particularly surgery. Present amount, $20,114. Annually available, approximately $633.

Holtzer (Charles W.) Fund. Income from $41,666.67 is used for general research. Apply to Director of Massachusetts General Hospital.

Richardson (Maurice Howe) Fund. Income for surgical research as recommended by the Chiefs of the General Surgical Staff of the Massachusetts General Hospital.

Tropical Medicine Fund, for study and care of tropical diseases. Present amount, $3076. Annually available, approximately $138.

Warren Triennial Prize. Established by the late Dr. J. Mason Warren in memory of his father. Awarded triennially for an original dissertation on some subject in physiology, surgery or pathological anatomy. Dissertations must be in either the English, French or German language, and must be typewritten and suitably bound so as to be easily handled. Work that has been published previously will not be considered in competition. Amount of prize, $500. Present fund, $7592.66. Essays will be received until November 15, 1934 for the current award.

MASSACHUSETTS HORTICULTURAL SOCIETY, 300 Massachusetts Ave., Boston, Mass.

Dawson (Jackson) Fund. Established 1925, by the Horticultural Club of Boston, the interest to be used for prizes, lectures and medals, or to commend and encourage the science and practice of hybridization and propagation of hardy woody plants. Present amount, $3227.

Lyman (Theodore) Fund, No. 2. Established 1850, the income to be appropriated for the encouragement of the growth of fruits or vegetables or plants, or of all three, by the distribution of prizes or premiums or in the publication of useful or valuable works on the general subject of horticulture; or if it shall not be thought advisable so to employ the whole of the net income of the fund, then to appropriate a part of it in some uniform and specific way for the promotion of horticulture. Present amount, $10,000.

Russell (John Lewis) Fund. Established 1889, the interest to be paid annually to some competent person who shall deliver a lecture on the latest discoveries of the connection of the fungi with horticulture. Present amount, $1000.

White (George Robert) Medal of Honor Fund. Established 1909, the income to be devoted annually for the specific purpose of providing a substantial gold medal to be awarded by the executive management of the Society to the man or woman, commercial firm or institution, in the United States or of some other country, that has done the most in recent years to advance the interest in horticulture in its broadest sense. Present amount, $10,000.

There are a number of other funds for medals, prizes, etc., to encourage the introduction of new plants, fruits and flowers.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY, Cambridge, Mass.

Cabot (Samuel) Fund, for research in industrial chemistry. Present amount, $54,000. Annually available, $2200.

General Budget Appropriations, for research in all departments. An nually available, estimated over $50,000.

Richards (Ellen H.) Fund, for research in chemistry. Present amount, $21,000. Annually available, $900.

Richardson (Charlotte B.) Fund, for industrial chemistry. Present amount, $46,000. Annually available, $1900.

Rockefeller Foundation, for research in physics, chemistry, biology and geology. Annually tapering grants. Available in 1934, $30,000.

Textile Research Fund, for research in textiles. Present amount, $31,000. Annually available, a variable amount.

Whitney Fund, for research in seismology. Present amount, $59,000. Annually available, $2500.

MATHEMATICAL ASSOCIATION OF AMERICA, W. D. Cairns, Secretary-Treasurer, Peters Hall, Oberlin, Ohio.

Carus Publication Fund. Established 1922, by Mrs. Mary Hegeler Carus, for the publication every year or two in monograph form of an expository account of some fields of collegiate or graduate mathematics, for the non-specialist. Original amount, $1200. Present amount, $5565. Annually available, $300 to $500 and cost of printing each monograph.

Chauvenet Fund. Established 1926, to promote expository articles on mathematical subjects. $100 every three years for the most notable article in mathematical exposition in the preceding three years.

MEAD JOHNSON AND CO., Evansville, Ind.

Mead Johnson Vitamin A Award. Established January 30, 1932, by Mead Johnson and Company, to stimulate vitamin A research, and specifically to determine the clinical value of vitamin A (if any) in human medicine. Present amount, $20,000. Two awards will be made: one of $15,000 for that investigation which determines the clinical value of vitamin A (if any) in human medicine, or determines the vitamin A requirements of human beings, or determines whether vitamin A in amounts more than is contained in a well-balanced diet is of benefit in human physiology; and a second of $5000 for that laboratory investigation which contributes most toward the attainment of the object of the larger award, or which contributes most toward an understanding of the physiology or pathology of vitamin A. The award will be administered by a group of nine judges. The second award will be made on the basis of papers accepted for publication by December 31, 1934; the first award will be made either at the same time and on the same basis, or, at the discretion of the Judges, on the basis of papers accepted for publication by December 31, 1936.

MEDICAL ASSOCIATION OF GEORGIA, Allen H. Bunce, M.D., Secretary-Treasurer, 139 Forrest Ave., N. E., Atlanta, Ga.

Hardman (L. G.) Silver Loving Cup. For meritorious work by members of the Medical Association of Georgia. The name is selected annually with statement of achievement, inscribed on cup, and re-deposited in the Treasury of the State of Georgia.

Long (Crawford W.) Memorial Prize. Established 1926, by anonymous donor, to encourage scientific research work by members of the Medical Association of Georgia. Awarded annually for original work.

MEDICAL COLLEGE OF VIRGINIA, Richmond, Va.

The following special grants for research have been received: $12,000 from the Chemical Foundation distributed over a three year period; $2000 a year from the Valentine Meat Juice Company for a period of three years.

MEMORIAL HOSPITAL, 106th St. and Central Park West, New York, N. Y.

Fuller Fund. Annual grant of $3000 from Trustees of Fuller Fund for the years 1933 and 1934.

Harkness Fund. Established 1927 for research. Present amount $50,000. Income available.

Huntington Fund. Established 1902, for cancer research. Principal, $100,000. Income available.

International Cancer Research Foundation. Annual grant of $2000 for the year 1933-34.

Littauer Fund. Established 1927, for five years; renewed in 1933. $2000 annually.

Peters Fund. Established 1932. Principal, $25,000. Income available.

Rockefeller Fund. Established 1927 and renewed in 1932. $25,000 annually for five years.

METROPOLITAN LIFE INSURANCE COMPANY, New York, N. Y.

Fund received from the Trustees of the Hegeman Estate, for the purpose of erecting and maintaining a research laboratory at Mt. McGregor, N. Y., as a memorial to the late John R. Hegeman. Total amount received was approximately $350,000. The erection and equipment of the Laboratory reduced this fund to about $300,000, the interest on which is used to support and conduct research activities in the field of tuberculosis.

The Company, during the past decade or more, has initiated and carried out a number of inquiries, investigations and experiments that constitute important contributions to research in the fields of medicine, public health and social welfare. These have been financed entirely by the Company, with the exception of occasional studies where other agencies such as voluntary health groups, universities and governmental units have participated and cooperated.

MIAMI UNIVERSITY, Oxford, Ohio.

Scripps Foundation for Research in Population Problems. Established 1922, by E. W. Scripps, to study problems arising from the growth of population. Original amount, $250,000. Annually available, $15,000 to $25,000.

About $800 is available each year for miscellaneous research problems by members of the faculty of the University.

MICHAEL REESE HOSPITAL, NELSON MORRIS MEMORIAL INSTITUTE FOR MEDICAL RESEARCH, 29th St. and Ellis Ave., Chicago, Ill.

General Research Fund. In accord with the research policy of the hospital to foster several major types of research, all research funds have been merged into one.

MICHIGAN COLLEGE OF MINING AND TECHNOLOGY, Houghton, Mich.

Research appropriation of $17,000 a year is made by the State to promote research on the iron and copper resources of Michigan.

MICHIGAN, UNIVERSITY OF, Ann Arbor, Mich.

Baird (James) Exploration Fund. Established 1931, by James Baird. The initial endowment was for scientific field work. The income is to be used for such purposes as the officials of the University may direct. Original amount, $5000.

Drug Addiction Research Fund. An initial appropriation of $10,000 was made by the National Research Council in 1930 to meet the expenses of a study of the biological action of various synthetic substances, prepared at the University of Virginia by chemical methods, in the field of drug addiction. The study has been supported since that time by annual appropriation.

Faculty Research Fund. Established 1927, to aid in meeting the expenses of research by members of the faculty (but not exclusively limited to scientific research). Present amount, $16,500. Allotments are made by a committee.

Institute of Fisheries Research. Established 1930. In years past the Michigan Division of the Isaac Walton League of America contributed funds, but at the present time the work is being supported by the Michigan Department of Conservation with small sums from other sources. The purpose of the fund is the investigation of game fish problems. Various amounts from $5000 to $20,000 are available from year to year.

Kellogg Company of Battle Creek. A fund of $20,000 has been contributed over a period of two years for research on effect of caffeine.

Pack (George Willis) Forestry Foundation. Established 1930, by gift of Charles Lathrop Pack in memory of his father. The income is used for the salary and expenses of the George Willis Pack Professor of Forest

Land Management. Present amount, $196,585. In 1932-33 the income was about $11,800, including a further gift from the donor to supplement interest on the endowment.

Patents Receipts Research Fund. This fund consists of the receipts of the University from its share of the royalties on patents developed through the Department of Engineering Research. It is administered by the administrative committee of the Department of Engineering Research and may be used for the researches of that and other departments of the University. On January 31, 1934 the balance in this fund was $24,985.

Russel (Henry) Lectureship and Henry Russel Award. The Lectureship is given each year to a member of the faculty on the basis of outstanding distinction in research. The lecturer is chosen by the Council of the Research Club of the University. The award is made to the Instructor or Assistant Professor who shows most promise of distinction in scholarship and research or in service to the University. The recipient of the award is chosen annually by a special committee. Neither of these items is strictly limited to scientific subjects. Each consists of $250, being half the income of the bequest of the late Henry Russel of Detroit, first available in 1926.

Simpson (Thomas Henry) Memorial Institute for Medical Research. Established 1927, by Mrs. Thomas Henry Simpson of Detroit, for research on the cause and cure of pernicious anemia; provision is made for directing the research in some other direction if in future it seems advisable. The gift consists of a building with equipment, valued at $238,000, and an endowment fund of $246,000 as funds available for carrying on the institute. In addition to the income from the endowment, the University appropriated in 1933-34 $1071 from its general funds. In addition the Simpson Memorial Institute Liver Extract Fund, derived from royalties on a liver extract developed at the Institute, and Parke, Davis and Company Ventriculin Fund, similarly derived from royalties on ventriculin, a product of desiccated hog stomach, are available for expenses of the research and other activities of the Institute. The income of these two funds during 1932-33 was about $5500.

Slocum (George) Research Fund. Established 1933, by bequest of George Slocum, one-half the income of which is to be added to the income of the John E. Weeks Scholarship for research in ophthalmology, the other half to be added to the principal of the George Slocum Research Fund until the income shall amount to $1000 a year, after which time the entire income of the fund may be used for research in ophthalmology as advised by the President.

Wheeler (Orlando B.) Fellowship and Publication Fund in Astronomy. Established 1928, by a gift from Mrs. Orlando B. Wheeler of Altadena, Calif. in memory of her husband. The income is to be used for Observatory publications in astronomy or for graduate research fellowships in astronomy at the discretion of the Director of the Observatory. Capital, $15,000. Income 1923-33, $665. The fund is being chiefly devoted to publication at the present time.

Ziwet (Alexander) Fund. Established by bequest of the late Professor Alexander Ziwet who died in 1928. The income of the fund may be used for the promotion of scientific work. It is, however, subject to an annuity of $1000 to be paid to the donor's sister during her lifetime. The amount of the fund at the present time is $82,170.

Zonite Products Corporation Research Fund. Established 1933, by the Zonite Products Corporation, to investigate the therapeutic effects of concentrated sap of the Mexican agave plant. Annually available, $6000 per year for two years.

MINING AND METALLURGICAL SOCIETY OF AMERICA, 76 Beaver St., New York, N. Y.

Gold Medal. Established 1914, for especially meritorious services in some branch of mining or metallurgy. Not restricted to members. Awarded only as occasion arises.

MINNESOTA, UNIVERSITY OF, Minneapolis, Minn.

$25,000 a year is available from the general university budget for medical research; this is a state appropriation for the years ending June 30, 1934, and June 30, 1935.

American Academy of Arts and Sciences Fund in Astronomy. A gift to be used in connection with a study of the proper motions of the stars.

American Creosoting Company Research Fund (Wood Preservative). A gift of $500 from the American Creosoting Company, to establish a fund to be used for labor and other expense necessary for the conduct of the research on "A Study of the Efficacy of Wood Preservatives." Approved by the Board of Regents May 9, 1933.

American Medical Association in Relation of Iodine to Goiter Fund. A gift of $200 for research in relation of iodine to goiter. Approved by the Board of Regents October 7, 1933.

American Medical Association Therapeutic Research Grant No. 159. A gift of $250 from the above organization to be used for an investigation of the concentration of calcium and magnesium in the blood. An additional gift of $250 was approved by the Board of Regents March 3, 1933.

American Society of Heating and Ventilating Engineers Co-Operative Research Fund. This society, in April, 1927, established a fund for the purpose of conducting research work in heating and ventilating. This gift was accepted by the Board of Regents August 25, 1927. At the present time the gift is $1750 a year.

American Society of Heating and Ventilating Engineers—Lumber Research Fund. A gift of $5000 to finance a series of experiments to determine the heat insulation properties of a selected list of woods to be furnished by the National Lumber Manufacturers Association. Approved by the Board of Regents July 18, 1930.

American Society of Mechanical Engineers Research Fund. A gift of $500 in August, 1928, from the American Society of Mechanical Engineers and the Engineering Foundation for the support of research work on fluid flow under direction of the Special Research Committee on Velocity Measurement of Fluid Flow.

Ansul Chemical Company Research Fund. A gift of $100 to be used by the Division of Plant Pathology and Botany for the purpose of determining the value of formaldehyde dust in controlling cereal diseases. Approved by the Board of Regents April 21, 1932.

Davis Permanent Trust Fund. Professor E. W. Davis of the School of Mines invented an ore washing machine and, by agreement with the University dated December 13, 1915, the patent was assigned to the Minneapolis Trust Company as trustee with the provision that the University should receive: 1. twenty-five percent of the net income, one half of which is to be used by the Board of Regents of the University to encourage and develop research work in the School of Mines along mining and metallurgical lines, the other half to be permanently invested and the income therefrom to be used for the above purpose; 2. fifteen percent to be paid to the director of the School of Mines Experiment Station to be expended for investigation, improvement and enlargement of the usefulness of magnetic ore washers and similar lines of work. On November 10, 1922, the comptroller of the University directed the division of this fund into three sections as follows: 1. Davis Permanent Trust Fund, in which are to be carried all investments; 2. Davis Research Fund, in which is to be placed one half of the 25 percent of the net income as outlined above; 3. Davis Magnetic Ore Washer Fund, in which the fifteen percent of the net income is to be placed, to be available for use by the director of the School of Mines Experiment Station.

Firestone Fund for Research in Relation to Propagation, Protection and Collection of Plantation Rubber. A gift of $1000 annually from the Firestone Plantation Company for investigations to determine the value of certain fungicides in controlling white root rot, and the protective value of certain fungicides in treating cut surfaces of rubber trees. Also to make a study of environmental factors affecting the development of white root rot and other diseases. Approved by the Board of Regents April 27, 1934.

Flaxseed Development Fund. The Flax Development Committee of the Eastern Paint and Oil Dealers, New York City, on April 11, 1923, gave $1000 to defray the expense of making a research to investigate the growth of flax and wheat as a combined crop.

Fluid Research Fund. A gift of $275,000 from the Rockefeller Foundation for a period beginning January 1, 1931, and ending June 30, 1937. This is to be used to support any type of deserving research presented to the University by competent members of the staff. Available, July 1, 1934 to June 30, 1935, $45,000; July 1, 1935 to June 30, 1936, $30,000; July 1, 1936 to June 30, 1937, $15,000.

Fox Breeders' Distemper Research Fund. The Fox Breeders' Distemper and Research Committee, on May 3, 1926, donated $150 to make a study of distemper. This gift has been supplemented by additional gifts, the investigation being now conducted to make a study of distemper with special reference to silver foxes.

Harris Memorial Research Fund. A gift of approximately $475 to be used for the aid or furtherance of research in fields in which Dr. J. Arthur Harris was interested. Approved by the Board of Regents May 7, 1930. Additional gifts have been received from time to time.

Heat Insulation Research Fund. The Flaxlinum Insulating Company, of St. Paul, on December 12, 1922, made a gift of $1000 to investigate the insulating properties of materials. This fund was composed of $3000 donated by three companies in 1928, at the rate of $1000 each. This fund was originally known as the Flaxlinum Research Fund.

Jenks Research Fund for Anthropological Exploration. A gift of approximately $9500 per year for five years beginning with 1929-30 from Mrs. George C. Christian, F. G. Atkinson, James Ford Bell, Joseph Chapman, F. M. Crosby, E. W. Decker, E. C. Gale, F. L. Heffelfinger, F. E. Murphy, A. F. Pillsbury, F. B. Snyder, John R. Van Derlip and Carl Jones for the establishment of the above named fund. Accepted by the Board of Regents May 28, 1929.

Kendall Thyroxin Fund. Professor E. C. Kendall, Mayo Foundation, Rochester, assigned to the University a patent covering thyroxin. Under this assignment a sum not to exceed 10 percent of the income from the sales of thyroxin may be paid to E. C. Kendall or to his wife and heirs at law. The assignment further provides that the remaining sum shall be expended for research into the physical and chemical properties and mode of action particularly of the substance now known as hormones in the animal organism, and generally, into the physical and chemical properties and mode of action of the substances now known as enzymes.

Lactona Incorporated Dental Research Fund. A gift of $1600 to determine the relative merits of certain ingredients in tooth paste. Approved November 25, 1933.

Mayo Foundation for Medical Education and Research. Doctors William J. and Charles H. Mayo, of Rochester, Minnesota, on June 9, 1915, gave to the University securities totaling $1,671,000 and $16,084.83 in cash as part of a gift to total not less than $2,000,000. The income from this fund is to be used for graduate medical and surgical instruction and research. There is, also, a provision that 10 percent of the income shall be set aside as a " Contingent Fund " to be used in cases of emergency of unanticipated research investigation, experimentation or medical education not provided for in the budget of the current year as and when the Board of Regents may deem proper. This fund, as of June 30, 1933, contained securities totaling $2,067,918.85.

Medical Social Work Fund. On October 19, 1929, the Board of Regents accepted a gift of $500 to be used to assist graduate students of medical social work. The principal of the fund will be used, and the donors prefer that the recipients shall have been tested by at least one quarter in the training course for social and civic work or by work in a social agency of recognized standing. There have been additional gifts since the establishment of the fund.

Minnesota Valley Canning Company Research Fund. This company, located at Le Sueur, Minnesota, on June 8, 1926, established a fund of $1400 a year to be continued for five years for the purpose of enabling the University to make a study of the ways to develop the fundamental principles as applied to sweet corn improvement.

National Research Council Funds. The following grants have been made for the purposes noted: $750 for technical assistance in connection with a study of the proper motions of the stars. Given on condition that $250 be provided from some other source which provision was met by gift from American Academy of Arts and Sciences. Approved by Board of Regents

June 28, 1932. $400 for research in connection with the preparation of gases of the methane series with the heavy isotope of hydrogen. Approved January 24, 1934. $750 for technical assistance in the study of internal structural changes taking place in a freshly prepared crystalline precipitate on standing. Approved by Board of Regents Oct. 8, 1932. $1000 to be used for technical assistance in a study of the chemical reactions produced in gases and other dielectrics by passage of electrical discharge. Approved by Board of Regents October 31, 1931. $500 for a survey of bacteria in a fresh water lake. Approved by Board of Regents January 24, 1934.

Oliver Iron Mining Company Research Fund. A gift of $1000 for work on the geological concentration of iron ore. Approved by the Board of Regents June 7, 1930.

Reyerson Research Fund. Dr. L. H. Reyerson on September 24, 1925, gave to the University 10 percent of the net income from a patent which he obtained on a process for metallizing silica gel. This is to be used in the School of Chemistry.

Rock Analysis Laboratory. A gift of $3000 a year for five years from the Rockefeller Foundation for the establishment of a laboratory for rock analysis, with the understanding that no more than $3000 shall be used in any year. Accepted by the Board of Regents May 28, 1929.

Rohm and Haas Company Research Fund. A gift of $150 from Rohm and Haas Company, to be used for part-time services of a chemist during a period of three months. Not more than $125 to be used for services. The remainder to be used for the purchase of special supplies and materials required for the research. Approved by the Board of Regents January 31, 1933.

Ruffed Grouse Research Fund. A gift of $200 for research on the life history and ecology of the grouse.

Toltz (Max) Fund for Engineering Research. Max Toltz of St. Paul, Minnesota, bequeathed to the University of Minnesota without condition, the sum of $15,000 to establish in the Engineering Experiment Station of the University of Minnesota a fund for research, the principal to be invested and only the income to be used. Accepted by the Board of Regents April 21, 1932.

Western Red Cedar Association Research Fund. A gift of $200 from the Western Red Cedar Association for an investigation of the electrical conductivity of red cedar and southern pine poles. Approved by the Board of Regents June 30, 1933.

MINNESOTA STATE HORTICULTURAL SOCIETY, R. S. Mackintosh, Secretary, University Farm, St. Paul, Minn.

Bronze Medal. Established about 1920. Awarded annually for meritorious service or eminence in horticulture, for the production of a new variety of fruit, flower, vegetable, shrub or tree of outstanding merit or importance. Not more than six medals a year may be offered.

MISSOURI BOTANICAL GARDEN, St. Louis, Mo.

In 1909, the Estate of Henry Shaw established a fund for research and instruction and the Rufus J. Lackland Fellowships. Annually available, $25,000.

MISSOURI SCHOOL OF MINES AND METALLURGY, Rolla, Mo.

Jackling Foundation. Established 1928, by Daniel Cowan Jackling of San Francisco, for education in the sciences and arts pertaining to the mineral industry. Original amount, $600,000. The Foundation is not as yet active, except for the Division of the Jackling Student Loan Fund.

MONTEFIORE HOSPITAL FOR CHRONIC DISEASES, Gun Hill Road, New York, N. Y.

Schiff Research Laboratory Fund. Established 1909, for research in medicine. Original amount, $100,000. Present amount, $590,000. Annually available, $28,000.

Wolff Cancer Research Fund. Established 1912, for the study of the cancer problem. Original amount, $50,000. Present amount, $50,000. Annually available, $2375.

MUSEUM OF THE AMERICAN INDIAN, HEYE FOUNDATION, Broadway at 155th St., New York, N. Y.

Established for research in archaeology and ethnology of the American aborigines.

NATIONAL ACADEMY OF SCIENCES, Washington, D. C.

Agassiz (Alexander) Gold Medal. See Murray Fund.

Bache (Alexander Dallas) Fund. Established 1867, by bequest of Alexander Dallas Bache, for the prosecution of researches in physical and natural science, by assisting experimentalists and observers in such manner and in such sums as shall be agreed upon by the Board of Directors. Present capital fund, $60,000.

Barnard Medal for Meritorious Services to Science. Established 1891, under the will of F. A. P. Barnard, to be awarded at the close of every quinquennial period to such person, whether a citizen of the United States or of any other country, as shall, within the five years next preceding, have made such discovery in physical or astronomical science, or such novel application of science to purposes beneficial to the human race, as in the judgment of the Academy shall be esteemed most worthy of such honor. The fund is administered by Columbia University.

Billings Fund. Established 1914, by Mrs. Mary Anna Palmer Draper, in honor of John Shaw Billings, to be used for the partial support of the Proceedings of the Academy, or for such other purposes as the Academy may select. Original amount, $1000 annually during Mrs. Draper's life, and $25,000 at her death. Amount received, $22,313.

Carty (John J.) Fund. Established 1930, by the American Telephone and Telegraph Company in recognition of the distinguished achievements of John J. Carty as a scientist and engineer, to provide a medal and monetary award, not oftener than once in every two years to an individual for noteworthy and distinguished accomplishment in any field of science coming within the scope of the charter of the National Academy of Sciences. Capital Fund, $25,000.

Comstock (Cyrus B.) Fund. Established 1907, by Cyrus B. Comstock, to advance knowledge in electricity, magnetism and radiant energy by the giving of money prizes for important investigations or discoveries (to be known as the Comstock Prizes). Awarded every five years to the bona fide resident of North America, who not less than one year nor more than six years before the awarding of the prize shall have made, in the judgment of the Academy, the most important discovery or investigation in electricity, magnetism or radiant energy. If no such discovery or investigation shall be deemed worthy, or if for any other reason the prize shall not be awarded for any period of five years, the money shall be added to the principal, or at the discretion of the Academy used to aid such investigations as are deemed worthy in these three subjects, by residents of North America. The prize may not be so diverted oftener than once in fifteen years. Present capital fund, $12,406.

Draper (Henry) Fund. Established 1883, by Mrs. Mary Anna Palmer Draper, for a gold medal to be awarded every two years for the most important original discovery in astronomical physics, preference to be given, in case of discoveries of equal importance, to a citizen of the United States. Any surplus may be used to aid investigations in the same subject by citizens of the United States. Present capital fund, $10,000.

Elliot (Daniel Giraud) Fund. Established 1917, by Miss Margaret Henderson Elliot, to award annually a gold medal, a diploma and the balance of the income to the author of the most worthy paper, essay or other work upon some branch of zoology or paleontology published during the year. Present capital fund, $8000.

Gibbs (Wolcott) Fund. Presented in a sum of $2600 to Dr. Gibbs on his seventieth birthday, 1892, and given by him to the Academy as a trust fund, to become available at his death, for chemical research. In 1913 the fund was increased by a bequest of Morris Loeb, amounting to $2500. Present capital fund, $5545.

Gould (Benjamin Apthorp) Fund. Established 1897, by Miss Alice B. Gould, in memory of her father, for the prosecution of researches in astronomy, by assisting observers and investigations. Present capital fund, $20,000.

Hartley (Marcellus) Fund. Established 1913, by Mrs. Helen Hartley Jenkins, in honor of her father, to provide a gold medal to be awarded for eminence in the application of science to the public welfare. Original capital fund, $1500. Present amount, $1200. The medal is known as the Public Welfare Medal.

Henry (Joseph) Fund. Established 1878, by friends of Joseph Henry, the income to be paid to him and his family during their lives. At the death of the last heir, in 1920, it became available to assist meritorious investigators, especially in the direction of original research. Original capital fund, $40,000. Present amount, $40,163.

Marsh Fund. Established by bequest of O. C. Marsh, for the purpose of promoting original research in the natural sciences. Final payment on the gift received July, 1915. Original amount, $10,000. Present amount, $20,000.

Murray Fund. Established 1911, by Sir John Murray, to found an Alexander Agassiz Gold Medal, to be awarded to scientific men in any part of the world, in recognition of outstanding original contributions to the science of oceanography. Present capital fund, $6000.

Public Welfare Medal. See Marcellus Hartley Fund.

Smith (J. Lawrence) Fund. Established 1884, by Mrs. Sarah J. Smith, in memory of her husband, for a gold medal to be awarded from time to time (not less than two years), for important original investigations of meteoric bodies, preference to be given, in case of equal importance, to one made by a citizen of the United States. Income not needed for this purpose may be used in aid of investigations of meteoric bodies, to be made by a citizen of the United States. Original capital fund, $8000. Present amount, $10,000.

Thompson (Mary Clark) Fund. Established 1919, by Mrs. Mary Clark Thompson, the income of which is to be applied to a gold medal to be awarded annually for the most important services to geology and paleontology, to be known as the Mary Clark Thompson Gold Medal. By vote of the Council of the Academy in 1923, the accumulating income balance is allowed to remain at interest apart from the capital fund until it has reached some substantial amount as $1000, as which time it will be given as a cash award to someone still actively working and in need of financial assistance in the sciences for which the fund stands. This is to be known as the Thompson Contingent Award. Present capital fund, $10,000.

Walcott (Charles Doolittle) Fund. Established in 1928, by gift of Mary Vaux Walcott in memory of the work of her husband, Charles Doolittle Walcott, for an inexpensive medal and an honorarium, to be awarded every five years, to encourage and reward individual achievement in advancing our knowledge of pre-Cambrian or Cambrian life and history in any part of the world. Original capital fund, $5000.

Watson (James Craig) Fund. Established 1880, by bequest of James Craig Watson, for the promotion of astronomical science. The income may be applied to grants of various sums to assist the completion of worthy researches in the field of astronomical science; the awarding from time to time of a gold medal, to persons in any country making an astronomical discovery or producing an astronomical work worthy of special reward as contributing to the progress of astronomy; setting aside annually a sum for work on the smaller planets discovered by the testator. Present capital fund, $25,000.

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS, 80 Federal St., Boston, Mass. Russel T. Fisher, Secretary.

Association Silver Medal. Established November 22, 1895, by the Board of Government of the Association. Granted only when, in the opinion of the Medal Committee of the Association, some one individual has contributed an outstanding service or achievement to the industry. While it can be awarded annually, there is no award unless it is merited. On occasion there have been two medals awarded in the same year.

NATIONAL ASSOCIATION OF DYERS AND CLEANERS, Silver Spring, Md.

An annual appropriation of $15,000 is made by the Association for research in the problems of dyeing and cleaning and the development of new methods and cleansing aids.

NATIONAL CANNERS ASSOCIATION, 1739 H St., N. W., Washington, D. C.

The Association maintains laboratories at Washington, San Francisco and Seattle, where research is carried on in chemical, bacteriological, technological and physiological fields. The Association also collaborates with other laboratories in work of mutual interest and makes grants to universities for research work connected with canning problems. During the last four years the expenditures annually have averaged $121,600.

NATIONAL CONFERENCE ON PHARMACEUTICAL RESEARCH, E. N. Gathercoal, 701 South Wood St., Chicago, Ill.

Grants for Research. During the year 1927, efforts on the part of the National Conference brought authorization of annual grants for research on the part of State Pharmaceutical Associations, said grants to be administered by a college of pharmacy within the specific State.

NATIONAL GEOGRAPHIC SOCIETY, Washington, D. C.

Research Fund. To collect original geographical knowledge by equipping and sending parties into the field, appropriations being recommended by the Committee on Research in each case. Annually available, $100,000.

Hubbard Gold Medal. For distinguished achievement in discovery and original geographical research; awarded but eight times in forty years.

Special Gold Medal. Occasionally awarded for the encouragement of original geographic research and achievement.

Other medals for distinct contribution to world knowledge along research lines are occasionally bestowed by the Society.

NATIONAL PAINT, VARNISH AND LACQUER ASSOCIATION, 2201 New York Avenue, N. W., Washington, D. C.

Research Laboratory maintained in Washington, supported by dues from the membership. The present annual income is something over $66,000.

NATIONAL RESEARCH COUNCIL, 2101 Constitution Ave., Washington, D. C.

The National Research Council expends funds for the encouragement and support of research in the physical and biological sciences which are derived from the income of an endowment of about $3,500,000, and from contributions made by various foundations and other organizations for specific purposes.

NATIONAL SAND AND GRAVEL ASSOCIATION, Munsey Bldg., Washington, D. C.

Approximately $15,000 were subscribed by members of the Association in 1928 to be used in the establishment of a research laboratory. Since then there has been an average annual amount of about $5000 spent in its operation and maintenance. The purpose of the laboratory is to carry out researches in order to improve the use of sand and gravel for structural and industrial purposes. As a result there have been progress reports presented through technical societies or trade publications on a considerable number of the different phases of the use of sand and gravel. Some of the complete reports have been published as bulletins or circulars of the Association. Members' products are subjected to special study upon their request, often leading to the development of new data in connection with the methods of investigation of mineral aggregates. The laboratory also cooperates in research programs of several technical societies and governmental organizations.

NATIONAL TUBERCULOSIS ASSOCIATION, 370 Seventh Ave., New York, N. Y.

Trudeau Medal. Established 1925, to be awarded not oftener than once a year to the individual who, in the judgment of the Association, has made the most meritorious contribution on the cause, prevention or treatment of tuberculosis.

The Association spends about $45,000 annually on research in tuberculosis through its Committee on Medical Research. In this program of research there are now cooperating three government divisions, eight universities, four endowed laboratories, two manufacturing chemical plants, seven volunteer health bodies and two semi-governmental bodies.

NATIONAL WARM AIR HEATING AND AIR CONDITIONING ASSOCIATION, Columbus, Ohio.

Research Fund. Established 1918, for research in warm air heating. Annual appropriation, $8000.

NEBRASKA, UNIVERSITY OF, COLLEGE OF MEDICINE, Lincoln, Neb.

McClanahan (H. M.) Fund. Established 1931, by H. M. McClanahan, to provide funds for carrying out pediatric research under the direction of the Department of Pediatrics. Capital, $30,000. Amount annually available depends upon the yield of the investment.

NEW ENGLAND PEDIATRIC SOCIETY, 319 Longwood Ave., Boston, Mass.

Morse (John Lovett) Prize. Established 1926, to promote scientific research among fourth year medical students.

One hundred and fifty dollar award. Established 1926, to promote scientific research among fourth year medical students. Award made in October each year. Papers submitted to Secretary, New England Pediatric Society.

NEW ENGLAND SOCIETY OF PSYCHIATRY, H. L. Paine, Secretary, Grafton State Hospital, Box Z, North Grafton, Mass.

New England Society of Psychiatry Prize Thesis. Established 1927, to stimulate research in psychiatry. Award to be made on basis of originality and quality of paper. Annually available, $150, for two awards of $100 and $50.

NEW HAMPSHIRE MEDICAL SOCIETY, Thomas W. Luce, Secretary, Portsmouth, N. H.

Pray (Thomas J. W.) Fund, for prize awarded annually for original essays upon some medical topic, the term "medical" being used in its broadest sense to include any branch of the profession. Original amount, $1000. Present amount, $1280. Annually available, $100.

Burnham (Hosea B.) Fund, for second prize awarded annually in the above contest. Original amount, $1140. Present amount, $2085. Annually available, $50.

Essays must be in the hands of the Secretary on or before May 1st.

NEW YORK ACADEMY OF MEDICINE, 2 East 103rd St., New York, N. Y.

Gibbs (Edward N.) Memorial Prize. Established 1901 by Sarah B. Gibbs and George Gibbs Sherrill, to promote research in diseases of the kidney. Original amount, $10,000. Present amount, $21,482. Annually available, $750.

Gold Medal. Established 1928, by Samuel McCullagh, M. D., to be awarded at infrequent intervals for unusually distinguished service in medicine. Original amount, $3000.

Salmon (Thomas W.) Memorial Award for Psychiatric Research. Established 1931, as a memorial to Dr. T. W. Salmon by friends and co-workers, to be used for the dissemination of knowledge in the control and prevention of mental and nervous disease, assistance in the presentation of new and important communications in the field of psychiatry and mental hygiene, and the assistance and initiation of research. As part of its program, the Committee has set aside a sum which will be available for small grants to physicians and others who are engaged in research in the field of psychiatry and mental hygiene. Applicants preferably should be associated with a university, hospital or established association or organization of good standing and should be endorsed by an officer of such an institution. Should the above conditions not obtain in a project of special merit, the applicant should make himself known to a member of the committee or to a psychiatrist prominent in the profession and obtain the endorsement of his work from such a person. Limited to modest grants. Applications are considered and acted upon April 20th and October 20th each year. They should be sent to the Thomas W. Salmon Memorial Committee, New York Academy of Medicine.

NEW YORK ACADEMY OF SCIENCES, 77th St. and Central Park West, New York, N. Y.

Audubon Publication Fund, for publication of research on some zoological or botanical topic. Established 1893. Original fund, $2500.

Centennial Endowment Fund, for scientific research and publication of research. Established 1917. Present fund, $7934.

Hermann (Esther) Research Fund, for research and publication of research in any branch of science. Established 1899. Original fund, $10,000.

Newberry (John Strong) Fund, for research and publication of research in geology, paleontology, botany or zoology. Established 1897. Original fund, $1000.

Tower (Ralph Winfred) Memorial Fund, for the publication of research. Established 1926. Present fund, $12,713.

The income of these funds, amounting to about 5 per cent of the principal, is available to members of the New York Academy of Sciences and Affiliated Societies upon vote of the Council of the Academy.

NEW YORK STATE COLLEGE OF FORESTRY, Syracuse, N. Y.

A sum of $7000 is available for forest investigation in the College, 1933-34.

NEW YORK ZOOLOGICAL SOCIETY, New York Zoological Park, New York, N. Y.

New York Zoological Society Special Research Fund. Established 1931, for studies in the periodicity of animal populations. Annually available, $2000.

NORDHOFF-JUNG (SOFIE A.) CANCER RESEARCH FUND, American Security and Trust Co., Washington, D. C.

Nordhoff-Jung (Sofie A.) Cancer Research Fund. Established 1923, by Dr. Sofie A. Nordhoff-Jung, for the encouragement of cancer research. Biennially available, $1000. The scope of the fund is international. It is awarded by a committee of four European scientists for outstanding achievements in cancer research.

NORTH CAROLINA, UNIVERSITY OF, Chapel Hill, N. C.

Fund for Research in Pure Science. Established 1926, by the General Education Board of the Rockefeller Foundation, to encourage scientific research. Annually available, $5000 a year. Allotted to professors in the University for specific research purposes.

Smith Research Fund. Established 1925, by a bequest of Robert H. Smith. Its object is to facilitate research of the faculty and students, including those in science. The income is administered by the Administrative Board of the Graduate School. Capital, $25,000. Annually available, $1500.

NORTH DAKOTA, UNIVERSITY OF, Grand Forks, N. D.

Lignite Coal Investigations and Research. Established by state appropriation and donations from coal companies. $3000 a year.

NORTHWEST RESEARCH FOUNDATION, Care Professor Lloyd H. Reyerson, University of Minnesota, Minneapolis, Minn.

The Northwest Research Foundation was incorporated July, 1933. It is expected that $50,000 will be available annually. This will be turned over to the University of Minnesota for the support of specific researches. The Foundation has an agreement with the University whereby any discoveries made under grants from the Foundation may be patented by the Foundation. The Foundation is to be reimbursed for its outlay of funds by any royalties based on these patents. After twice the amount donated by the Foundation has been returned to it, the University and the Foundation will share any additional returns equally. The University may use its share of these returns to support research of any character it may see fit.

NORTHWESTERN UNIVERSITY, Evanston, Ill., and Chicago, Ill.

There are in addition to the funds enumerated certain sums allotted each year from the University appropriations to individual research projects. These allotments are usually made on the recommendation of the faculty committee after consideration of the projects. The sum allotted is not fixed nor the purpose determined in advance.

Alumni Research Fund. Founded by Dr. A. S. Vail and others. Available for a member of the faculty to do research in medicine.

Camp (Walter M.) Fund. Established 1927, for planetary research. Annually available, $750.

Chicago Astronomical Society Research Fund. Established for research in astronomy. Original amount, $1500. Present amount, $1500. Annually available, $75.

Dearborn Observatory. Annual appropriation, $2500, one-half of which is to be used for research in astronomy.

Dental Research Fund. Established for dental research in the University. Original amount, $5480. Annually available, $411.29.

Dental Research Fund of 1923. Present amount, $4464. Annually available, $235.

Gilmer (Ella M.) Research Fund. Established 1932, for research in dental and oral surgery and medicine. Original amount, $1900. Annually available, $65.

Gilmer (Thomas) Research Fund. Established 1927, for dental research. Original amount, $11,225. Annually available, $711.

Harris (Norman W.) Lectures. Established 1906, to stimulate scientific research of the highest type and to bring the result of such research before the students and friends of the University. Annually available, $1000 to $1500.

Linthicum (Charles Clarence) Foundation. Established 1926, for cultivating research, study and instruction in patent law. Present amount, $12,000. Annually available, $600.

Mayo (Dr. Charles H.) Fund. Established for lectures on progress of surgery through research. Present amount, $5863. Annually available, $293.

Medical School Alumni Fund. Established 1904, for medical research. Present amount, $2657. Annually available, $132.

Patten (James A.) Fund. Established 1911, for medical research in bacteriology and tuberculosis. Present amount, $283,955. Annually available, $14,000.

Rea Bequest. Established 1902, for medical research. Original amount, $9700. Annually available, $485.

NOTRE DAME, UNIVERSITY OF, Notre Dame, Ind.

The University makes annual appropriations for supplies and facilities for theoretical and applied scientific research in the various departments of the Colleges of Science and Engineering. The amount to be spent in the year 1934-35 will approximate $7500.

OHIO ACADEMY OF SCIENCE, Ohio State University, Columbus, Ohio.

Research Fund of Ohio Academy of Science. Originally formed by annual grants from Emerson McMillin, and after his death the accumulated funds and additions from life memberships. Its purpose is to encourage research by grants in aid. Original amount, $1000. Present amount, $1500. Annually available, $50 to $100. Applications for grants should be filed with the Trustees of the Fund.

OHIO STATE ARCHAEOLOGICAL AND HISTORICAL SOCIETY, High St. and 15th Ave., Columbus, Ohio.

Exploration and Field Work. For exploration of earthworks of mound builders and Indian village sites, the State appropriated in 1932, $1370.

OHIO STATE UNIVERSITY, THE, Columbus, Ohio.

The fund available for the purchase of scientific apparatus and equipment is approximately $25,000 per annum. The Dean of the Graduate School is a member of the Committee on Appropriations and looks after the interest of research work of the University. This Committee makes all allotments from the above general equipment fund of the University.

OKLAHOMA, UNIVERSITY OF, Norman, Okla.

Faculty Research Fund. This fund is administered by a committee of the Graduate Faculty appointed by the President and the Dean. Applications are received on or before October 15th and March 15th and approved November 1st and April 1st. Application forms are furnished by the Dean of the Graduate School.

OPTICAL SOCIETY OF AMERICA, L. B. Tuckerman, Secretary, Bureau of Standards, Washington, D. C.

Ives (Frederick) Medal. Established 1928, by Herbert E. Ives, for distinguished work in optics. Present amount, $500. Annually available, interest. No applications received. Awarded on recommendations of a committee appointed by the Optical Society.

OREGON, UNIVERSITY OF, Eugene, Ore.

Eugene Water Board Grant. To further facilitate the study of the separation of the heavy hydrogen isotope supported by a grant from the National Research Council, the Eugene Water Board has provided electric power, material and labor to the extent of $2500.

National Research Council Grants. $800 was granted to the Chemistry Department in 1932 for the study of the separation of the heavy hydrogen isotope. In 1932 a grant of $400 was made for excavations at Gold Hill, Ore. and $100 for the study of petroglyphs in Oregon.

Portland Women's Research Club Grant. $1000 was granted in 1923 to establish a children's laboratory and bureau of research for the purpose of studying those types of children who do not adjust themselves adequately to the usual school and classroom situation. This study includes the mentally deficient, borderline cases, the speech defective, the truant, the delinquent, the non-reader, the child with deficient reading skills, the child unable to spell adequately, and the child with a deficient number sense.

Sigma Xi Graduate Research Prize. Established 1930 to stimulate graduate research. Awarded to a member of the Oregon chapter of Sigma Xi for the most outstanding research. Amount determined each year by the board of electors, usually about $25.

State Board of Higher Education in Oregon Appropriations. The State Board appropriates annually: 1. A sum of money for general research, varying from $12,500 for use on the University campus to $5000 to be divided between the University and the State College for the year 1933-34 when the latter sum is available. This grant is distributed by the General Research Council in small amounts to faculty members for the purpose of carrying out individual projects. 2. A sum of money for promoting the services which the University may render the state. This appropriation is administered by the Commonwealth Service Council. $5000 for 1933-34. 3. A sum of money for the purpose of conducting research in connection with the operation of the institution itself. $500 for 1933-34.

OREGON MEDICAL SCHOOL, UNIVERSITY OF, Portland, Ore.

Academy of Otolaryngology Fund. Established 1931, by the American Academy of Otolaryngology, Omaha, Neb., for research in sinusitis. $500.

General Education Board Fluid Research Fund. Established 1932, for general medical research. $6500.

Nutritional Research Laboratory. Established 1923, by sundry donors, chief of whom was Mr. E. S. Collins of Portland, for the biologic investigation of the nutritional causes of morbidity and mortality. $2400.

Research in Dental Pathology. Established 1931, by Dr. Leif and Mr. B. Underdahl of Portland, Ore., for research in oral pathology. $240.

Research on Vitamin in Apple. Established 1932, by the Washington Boxed Apple Bureau, Seattle, Wash., for research on vitamin in apples. $580.

Research on Vitamin in Pear. Established 1932, by the Oregon-Washington Pear Bureau, Seattle, Wash., for research on vitamin content of pears. $212.

OYSTER GROWERS AND DEALERS ASSOCIATION OF NORTH AMERICA, INC., 610 Quinnipiac Avenue, New Haven, Conn.

Research Fund. Established 1926, to obtain scientific information necessary for the development of the industry, particularly regarding nutritional value of oysters. Original amount, $10,000. Present amount, $7500.

PACIFIC COAST GAS ASSOCIATION, 447 Sutter St., San Francisco, Calif.

Certificate of Honor. Awarded to Gold Medal winners and to Chairmen and members of committees.

Day (Addison B.) Medal of Honor. Awarded to the Association member who is deemed to have rendered the outstanding individual service in behalf of the gas industry. Applications or nominations should be made prior to July 1st of each year.

Official Gold Medal. Awarded to members who contribute outstanding papers at the annual meetings. The approximate amount spent for these medals annually is $75.

PATHOLOGICAL SOCIETY OF PHILADELPHIA, Herbert L. Ratcliffe, Secretary, University of Pennsylvania, Philadelphia, Pa.

Gerhard (William Wood) Gold Medal. Awarded for medical research. Capital about $4000.

PENNSYLVANIA, UNIVERSITY OF, Philadelphia, Pa.

Cancer Research Fund of the Graduate School of Medicine. Established in 1927, and continued since then by various gifts, totaling to January 1, 1934, $404,729. The gifts were not in the nature of endowments but in the nature of funds, of which the principal is being expended as the discretion of the committee in charge.

Carnegie Corporation of New York Endowment Fund for Medical Research. Established 1927, by the Carnegie Corporation of New York, for medical research in the Medical School of the University. Principal, $251,611. Income, $8620.

Clark (Dr. John G.) Fund. Established August 13, 1931, by bequest under the will of Mrs. Elizabeth B. Ketterlinus of $150,000 held in trust, the income therefrom being used for the upbuilding of the scientific work of the Gynecological Division of the University Hospital. Annually available, $6832.

Clark (John G.) Memorial Fund. Established December 18, 1931, by sundry gifts, the income from which is used for special purposes relating to the study and care of patients of the Gynecological Division of the Hospital of the University of Pennsylvania, for the support of research or clinical assistants and for other similar purposes designed to improve the Gynecological Division. Principal $69,559. Annually available, $3721.

Clark Research Professorship of Assyriology Fund. Established 1902, by Edward W. Clark and Clarence H. Clark, for research in Assyriology. Present amount, $135,484. Annually available, approximately $4300.

Cox (George S.) Medical Research Institute Fund. Established July 6, 1931, by bequest of George S. Cox, for research into the cause and cure of diabetes. Principal $1,000,000, held by Trustees of the Estate of George S. Cox, deceased. Annually available, $25,000.

Donner Research Fund. A grant of $1500 has been made by The International Cancer Research Foundation for research work in connection with certain cancer investigations by Dr. Baldwin Lucke.

Duhring (Louis A.) Cutaneous Medicine Department Endowment Fund. Established 1915, by Dr. Louis A. Duhring, by bequest in his will, for the purchase of wax or paraffin or other kinds of models of cutaneous diseases, and for general requirements of the department. Present amount, $350,600. Annually available, approximately $15,000.

Ellis (Mary Bell) Prize Fund. Established 1923, by Dr. E. B. Krumbhaar, for a prize to be awarded the best piece of undergraduate medical research. Present amount, $500. Annually available, $20.

Frazier (Charles Harrison) Foundation for Neurological Surgery. Established 1929, by Mrs. John E. Zimmerman, for the development and progress of neurosurgical problems and the welfare and comfort of neurosurgical patients. Principal $52,885. Annually available, $3222.

Gibson (William) Fund. Established 1926, by Alfred C. Harrison, for research in surgery under the direction of the John Rhea Barton Professor of Surgery. Principal $10,012. Annually available, $555.

Hematology Fund. Gift of Mrs. Bruce Ford on November 15, 1933, of $500 for research in the work of the Hematology Section of the University Hospital.

Hirst (Barton Cooke) Foundation for Research in Obstetrics. Established 1929, by sundry gifts, for research activities in the Department of Obstetrics. Principal $7852. Annually available, $428.

Johnson (Eldridge R.) Foundation for Research in Medical Physics. Established 1927, by Eldridge R. Johnson, for the creation of the above Foundation. Original amount, $800,000, subsequently increased to $1,000,000. Of this sum, $200,000 was allocated towards the construction of the Martin Maloney Clinic and $800,000 is held inviolate as the endowment of the Foundation.

Kirby (Fred M.) Medical Research Fund. Established 1928, by Fred M. Kirby, for the study and prevention of nervous and mental diseases. Principal $125,000. Annually available, $7378.

Kolb (Louis J.) Fund for the Study and Treatment of Cancer. Established 1928, by Col. Louis J. Kolb, for the study and treatment of cancer. Total gifts to the fund aggregate $117,713. The funds concerned have been used for the stated purposes, the major expenditure having been for 1,245,362 milligrams of radium now in use for the above work.

McCarthy (Daniel J.) Research Fund. Established 1929, by Dr. Daniel J. McCarthy, for research in the general field of nervous and mental diseases. Principal $77,084. Annually available, $4016.

Maloney (Martin) Memorial Clinic. Established 1927, by sundry persons. Erected at a cost of $1,000,000. The Clinic is for the purpose of research in clinical medicine and the operation of various sub-clinics.

Mead Johnson and Company Research Fund (Department of Pediatrics). A further grant of $6000 has been made by Mead Johnson and Company for the continuation during 1933-34 of vitamin B research work now in progress under the direction of Dr. Joseph Stokes, Jr.

Morris Arboretum of the University of Pennsylvania. By a bequest under the will of Miss Lydia Thompson Morris, deceased, January 24, 1932, the Morris Foundation was established which, among other purposes, provides for botanical research and the dissemination of such knowledge through the Botanical Department of the University of Pennsylvania.

Musser (John Herr) Department of Research Medicine Fund. Established 1909, by Mrs. Harriet C. Prevost, for the support of the Department of Research Medicine which was established by this endowment. Capital, $212,434. Annually available, approximately $10,000.

Pennsylvania College of Dental Surgery Fund. Established March, 1918, by the Pennsylvania College of Dental Surgery, for scientific research and investigation in dentistry and the purchase of books related thereto. Principal $19,370. Annually available, $940.

Pepper (William) Laboratory of Clinical Medicine Endowment Fund. Established 1925, by the executors of the estate of Dr. William Pepper, for the endowment of the Laboratory. Capital $123,617. Annually available, approximately $5000.

Phipps (Henry) Institute Endowment Fund. Established 1920, by Mr. and Mrs. Henry Phipps, and further augmented in 1927 by a consolidation of other funds and by additional gifts and pledges. For the study, treatment and prevention of tuberculosis. Through the consolidation of other funds and the gift of $500,000 from Mr. and Mrs. Phipps, together with the gifts and pledges of others, this fund will have, eventually, a capital of $1,000,000, and is already receiving the income on that sum, approximately $40,000.

Physick (Philip Syng) Surgical Foundation. Established by sundry gifts for the advancement of surgical research. Principal $5394. Annually available, $275.

Robinette (Edward B.) Foundation for the Advancement of Medical Science and the Promotion of the Liberal Arts. Founded in 1928, by Edward B. Robinette, with an initial contribution of $250,000, to conduct a clinic for the study, treatment and prevention of diseases of the heart and the circulatory system, the capital to be increased by further gifts from the donor. Present amount $320,646.

Special Clinical and Research Fund. Gift of $5000 from an anonymous donor, September 12, 1933, to be used at the discretion of Dr. Truman G. Schnabel in his teaching and research efforts as a member of the teaching staff of the University of Pennsylvania.

Special Research Fund. Established December, 1930, by the Rockefeller Foundation by the appropriation of $80,000 to be made available during the period of five and one-half years beginning January 1, 1931, to further research work at the University of Pennsylvania in such manner as may be directed by the Trustees of the University of Pennsylvania.

Veterinary School Investigation Fund. Sundry gifts for the purpose of investigating diseases of cattle. Present amount $1134.

Warwick (Hill S.) Fund. Established 1927, by Miss Agnes Warwick and augmented by bequests of Dr. Hill S. Warwick and Miss Agnes Warwick, for the erection of a dormitory, the net income from which is to be devoted to the investigation of diseases of an infectious or contagious nature, with a view to finding a means for their prevention. Principal $184,925. Annually available, $6811.

The following grants have been made to the University for specific research projects:

American Medical Association—*Therapeutic Research Grant.* Established by a grant of $100 from the Committee on Therapeutic Research of the Council of Pharmacy and Chemistry of the American Medical Association, October 18, 1933, for an investigation of leucocytes attraction.

Commonwealth Fund—*Kidney Research Fund.* Appropriations aggregating $104,000 payable over a period of three years from July 1, 1931, for the study of the function of the kidney, the research to be carried on under the dirction of Dr. A. N. Richards in the Laboratory of Pharmacology of the School of Medicine of the University of Pennsylvania.

National Research Council—*Effects of Radiation upon Living Organisms Fund.* A further grant of $750 has been made by the Committee on Effects of Radiation upon Living Organisms for the period July 1, 1933, to June 30, 1934, in support of the work at the University of Pennsylvania of Dr. L. V. Heilbrunn on the action of ultraviolet rays and x-rays on protoplasm.

Effects of Salts and Other Environmental Factors on Protoplasm Fund. A grant of $300 has been made by the Committee on the Effects of Radiation upon Living Organisms of the National Research Council for the period July 1, 1933, to June 30, 1934, in support of the work at the University of Pennsylvania of Dr. William Seifriz on the effect of salts and other environmental factors on protoplasm.

Study of the Relation of Tuberculosis and Syphilis in Experimental Animals Fund. The National Research Council has made an appropriation of $250 to Dr. J. D. Aronson of the Henry Phipps Institute for the purchase of supplies in connection with his study of the relation of tuberculosis and syphilis in experimental animals.

National Tuberculosis Association—*Study of the Improvement of X-Ray Technique Fund.* Established March 19, 1929, by grant from the National Tuberculosis Association and continued by succeeding grants for the study of the improvement of x-ray technique. Amount available for the year ending June 30, 1934, is $4000.

Rockefeller Foundation—*Anatomy Research Fund.* An appropriation of $75,000 has been made for a period of five years beginning July 1, 1929, for researches by Dr. Eliot R. Clark.

Rosenwald Fund—*Department of Industrial Research Fund* (Julius Rosenwald Fund Gift). An appropriation has been made to pay $8333.33 annually for three years beginning with the academic year 1932-1933 to the Department of Industrial Research for studies in the regularization of employment.

PENNSYLVANIA PHARMACEUTICAL ASSOCIATION, J. B. Pilchard, Secretary, 227 State St., Harrisburg, Pa.

Twenty Dollar Gold Prize. Established 1908, to inspire papers on original research. Awarded for originality and value to pharmacy.

PHI LAMBDA KAPPA FRATERNITY, 1941 South 9th St., Philadelphia, Pa.

Gold Medal. Established 1928, for conspicuous achievement in the medical sciences. The recipient is chosen by a special Scientific Award Committee.

PHILADELPHIA ACADEMY OF SURGERY, 19 South Twenty-second St., Philadelphia, Pa.

Gross (Samuel D.) Prize in Surgery. Awarded every five years for the best original essay on a subject in surgical pathology or surgical practice, founded on original investigations. Candidates must be American citizens. Award will not be made if none of the essays is considered worthy. Essays in competition for the next award will be received until January 1, 1935. $1500.

PHILADELPHIA SOCIETY FOR PROMOTING AGRICULTURE, Villa Nova, Pa. George F. Curwen, Secretary.

Since the early days of the Society it has been the custom to grant prizes and awards for outstanding achievement in agriculture. These awards carry no money as there is no fund established for the purpose. They are usually made in the Spring, but there is no definite date set.

PLOTZ (ELLA SACHS) FOUNDATION, Dr. J. C. Aub, Collis P. Huntington Memorial Hospital, 695 Huntington Ave., Boston, Mass.

Plotz (Ella Sachs) Foundation for the Advancement of Scientific Investigation. Established 1923, for the advancement of scientific research. At present attention is directed towards investigations which bear on medicine and medical sciences. The Fund is not restricted to any country. Applications must be in the hands of the secretary by May 1st. Grants are made from the fund for purchase of apparatus and supplies needed for special investigations and for the payment of unusual expenses incident to such investigations, including technical assistance, but not for providing apparatus or materials which are ordinarily a part of laboratory equipment. Stipends for the support of investigators will be granted only under exceptional circumstances. Annually available, approximately $10,000.

PORTLAND CEMENT ASSOCIATION, 33 West Grand Ave., Chicago, Ill.

Since 1916 an annual appropriation for support of the Research Laboratory of the Portland Cement Association has been made by the Association. Its purpose is to discover facts about concrete and concreting materials which will help the users of Portland cement to make better concrete. The appropriation varies from year to year.

POULTRY SCIENCE ASSOCIATION, W. A. Maw, Secretary-Treasurer, Macdonald College, Quebec, Canada.

Poultry Science Research Prize. Established 1928, to encourage scientific research. Annually available, $100. All members of the Poultry Science Association, with the exception of heads of departments who comprise the committee on award, are eligible for the entering of a paper published during the current year for the Research Prize.

PRESBYTERIAN HOSPITAL, 620 West 168th St., New York, N. Y.

Baker (Mrs. Frederick) Pathological Department Fund. Established 1904, by Mrs. Frederick Baker, to supply books, periodicals and instruments for use in the Pathological Laboratory. Capital, $8000. Annually available, $400.

Briddon (C. K.) Gold Medal Fund. Established 1903, by Dr. Charles K. Briddon. The income provides a medal competed for every two years by members of the Alumni of the Presbyterian Hospital who write essays requiring original research. Original amount, $1000. Annually available, $60.

Dows (Mrs. David) Fund. Established 1909, by Mrs. Richard March Hoe. The income is used to purchase scientific instruments for use in the hospital for the study and cure of disease. Capital, $7700. Annually available, $385.

Faulkner (Edward Daniels) Memorial Fund. Established in 1928, by Mrs. Edward Daniels Faulkner, to pay for transfusions given in connection with research in arthritis. Original amount, $50,000. Present amount, $100,000. Annually available, $5000.

Fund for Educational and Scientific Work. Founded 1917, by the Charles W. Harkness Estate. The income is used for the educational and scientific work of the Hospital in accordance with the agreement between the Hospital and Columbia University. Original amount, $250,000. Present amount, $282,777. Annually available, $14,700.

Fund for Physical Diagnosis. Established 1929, by Mr. and Mrs. George C. Fraser, for research work in connection with physical diagnosis. Original amount, $5000. Present amount, $2427. Annual income not ascertainable.

Fund for Study of Bright's Disease. Established 1927, by Mr. Charles Hayden, to defray expenses of research and treatment of Bright's disease. Original amount, $1500. Present amount, $843. Annual income not ascertainable.

Fund for Study of Migraine. Established 1931, by the Josiah Macy, Jr. Foundation, to defray expenses of treatment and research in connection with migraine. Original amount, $2000. Present amount, $20.

Harkness Research Fund. Estbalished 1928, by Mr. Edward S. Harkness, for laboratory research work. Original amount, $250,000. Present amount, $500,000. Annually available, $25,000.

Hayden (Charles) Fund for the Benefit of the Coakley Clinic. Established 1930 by Mr. Charles Hayden, for research and special work under direction of Dr. Coakley. Original amount, $125,000. Present amount, $3394.

Medical Scientific Fund. Established 1927 by various donors. The income is used for educational and scientific work in the field of medicine. Original amount, $1000. Present amount, $317,225. Annually available, $15,861.

Ottmann Fund for Cancer Research. Established 1932 by the Estate of Madeleine L. Ottmann. The income is to be used to help defray expenses in connection with cancer research. Original amount, $20,000. Annually available, $1000.

Sloane Hospital Fund for Special Cancer Research. Established 1932, by Mrs. Alice Hought Dominick and Mrs. A. C. Thomson, to defray expenses in connection with special cancer research in the Sloane Hospital for Women. Present amount, $75.

Sloane Hospital Research Fund. Established 1931, by Mr. B. F. Smith, for special study of anaemia in pregnancy. Original amount, $25,000. Annually available, $1250.

Surgical Pathological Research Fund. Established 1930, by various donors, to help defray expenses of surgical pathological research. Original amount, $500. Present amount, $332.

Surgical Research Fund. Established 1930, by various donors, to cover unusual expenses in connection with the educational and scientific development. Original amount, $12,540. Present amount, $3731.

Wheeler Glaucoma Research Fund. Established 1931, by Mr. and Mrs. Reginald Auchincloss, for research in connection with diseases of the eye. Original amount, $334. Present amount, $416.

PRINCETON UNIVERSITY, Princeton, N. J.

Princeton Scientific Research Fund. Established 1928, by gift of $1,000,000 from the General Education Board, and $2,000,000 by subscription of alumni and friends of the University; the principal contributors of the latter were Miss Gwethalyn Jones and Mr. Thomas D. Jones of Chicago. To provide facilities for research in astronomy, biology, chemistry, mathematics and physics, in addition to those provided by the University. A portion of the fund was designated by the donors for the establishment of six Advanced Professorships, one each in the above subjects. The remainder of the income is spent for the purposes indicated each year by the President of the University who has an Advisory Committee of which the Dean of the Graduate School is chairman and each of the fields of science involved is represented. Original amount, $3,000,000. Annually available, about $130,000.

Scott (William Berryman) Research Fund. Established 1925, by friends of the University and of Professor W. B. Scott, to finance the interests of vertebrate palaeontology at Princeton University. The fund is administered by and for the University, for such purposes within the field of vertebrate palaeontology as the Administrator of the fund may decide. The field work of the fund is conducted under the name of Scott Fund Expeditions. No grants are available outside the University. Capital, $50,000. Annually available, $2500.

PURDUE UNIVERSITY, Lafayette, Ind.

A. R. A. Automatic Connectors Tests. Established 1930, by the American Railway Association, to determine the fundamental principles of automatic connectors and the practicability of such devices in service. Up to January 1, 1934, a total of $35,500 has been expended in connection with this investigation.

A. S. M. E. High Pressure Boiler Research. Established by Engineering Foundation through A. S. M. E. Research Committee, for experimental program on high pressure boilers. Up to March 1, 1934 a total of $1500 has been contributed to this fund.

Cleaner Corporation of American Research. Established 1932, by the Cleaner Corporation of America, for special research. Original amount, $2400. A special grant whose continuity is not guaranteed beyond the current year. Administered through the Purdue Research Foundation.

Draft Gear Research. Established 1926, by the American Railway Association, for the testing of draft gears. Total expended to date through the University, $90,845.

Duncan Mercury Circuit Breaker Fund. Established 1931, by the Duncan Electric Manufacturing Company, for research in connection with the Duncan mercury circuit breaker. Up to March 1, 1934 a total of $1762 has been expended in connection with this project.

Engineering Experiment Station. Established 1917, to afford opportunities for scientific research in engineering. Original amount, $15,000; $12,652 available from University budget.

Utilities Research Fund. Established 1928, by the Utilities Research Commission of Chicago, for investigations on the effect of lightning on transformer secondary circuits, the proper procedure for making successful welds with city gas, weather proof insulation for line wires, welding by use of natual gas and delayed recording of electrical disturbances. Total expended up to December 31, 1933, $112,150.

AGRICULTURAL EXPERIMENT STATION

Agricultural Experiment Station Fund. Established 1905, to provide for research and investigations in connection with production of farm products and stock raising. Annually available, $226,000.

Corn Borer and Codling Moth Fund. Established 1927, for the control and eradication of European corn borer and Japanese beetle and other destructive insect pests and plant diseases. Annually available, $30,000.

Farm Electricity Fund. Established 1925, for investigations on electricity in relation to agriculture. Annually available, $7500.

Indiana Canners Research Fund. Established 1920 by the Indiana Canners Association for raw products research. Present amount, $3000.

Potash Research Fund. Established 1925, by the N. V. Potash Export My, of Amsterdam, Holland, to establish a center for the field and laboratory study of potash deficiency problems on various crops. Such work will include any part of the United States as the detailed plans from time to time might be agreed upon to cover. Annually available, $13,000.

Southwestern Millers Fund. Established 1930, by Southwestern Millers Association. A grant of $5000 for five years, beginning 1930.

RADIOLOGICAL SOCIETY OF NORTH AMERICA, 607 Medical Arts Bldg., Syracuse, N. Y.

Gold Medals. The Board of Censors in conjunction with the Executive Committee award not more than four gold medals a year to individuals who have served the science of radiology.

RENSSELAER POLYTECHNIC INSTITUTE, Troy, N. Y.

General budget appropriation for research in all departments. Annually available, generally from $4000 to $6000.

Class of 1902 Fund. The Class of 1902 has established a fund of $3000, the net income from which is to be used for a prize for the best thesis involving experimental research.

Laflin (L. E.) Fund. Established 1915, by Louis E. Laflin, for research. Open to students, graduate and undergraduate. Capital, $10,000. Annually available, income.

RESEARCH CORPORATION, 405 Lexington Ave., New York, N. Y.

Research Corporation was organized for the purpose of public administration of such patent rights as it might from time to time receive. It was granted the patent rights covering the use of the Cottrell Electric Precipitation Process in certain territories. Such sums as might be earned from the exploitation of these patent rights were to be made available for further research. The policy of the Board of Directors is to withdraw funds from the commercial activities of the Corporation and make appropriations for research when the business of the Corporation warrants such withdrawals. Therefore, these appropriations for research are made irregularly and for no stated amounts. Grants may be made only through institutions. It is not essential that the specific institution through which the grant is to be made be stated in the application as long as it is understood that if the research is supported, the applicant will arrange with some suitable institution to administer the funds. Applications should be received by January 1st.

Prizes. A plaque with a cash award is given at irregular intervals for outstanding achievement in science. The prizes are given preferably to scientists who have made a valuable contribution for which no previous recognition has been received.

RHODE ISLAND MEDICAL SOCIETY, Providence, R. I.

Fiske Fund. Established 1835, by Caleb Fiske, for the advancement of medical science. Present amount, $11,814.99. Prize awarded for best essay on medical subject selected by Trustees and announced annually at the annual meeting of the Rhode Island Medical Society.

ROCHESTER, UNIVERSITY OF, Rochester, N. Y.

In the College of Arts and Science of the University there is a fund of $750,000 contributed by the General Education Board in 1927, the income of which is to be used to provide research and advanced instruction, particularly in the biological and physical sciences.

In the School of Medicine and Dentistry, founded by gifts made in 1920 by George Eastman and the General Education Board, there is an endowment of approximately $10,000,000, the income of which provides for the conduct of medical education and medical research, together with the maintenance of a teaching hospital.

Vital Economics Fund. Established 1915, by bequest of the late Lewis P. Ross, for instruction and experimentation in physiology, hygiene and the nutrition of the human body to the end that human life may be prolonged with increased health and happiness. The Department of Vital Economics is organized on the basis of combined research and instruction, research occupying the major attention of the personnel. Annually available, $25,000.

ROCKEFELLER FOUNDATION, THE, 49 West 49th St., New York, N.Y.

The program of The Rockefeller Foundation is directed toward the advancement of knowledge in the fields of medical science, natural science, social science, the humanities and public health. Except to a limited degree in public health, the Foundation is not an operating or research agency. It gives assistance, both directly and through aid in the training of personnel, to universities and other agencies carrying on research of a fundamental character; and in addition, in the field of public health, it cooperates with governments in the development of general public health activities and the study and control of certain diseases.

ROCKEFELLER INSTITUTE FOR MEDICAL RESEARCH, THE, 66th St. and York Ave., New York, N. Y.

The Rockefeller Institute for Medical Research. Established 1901, by John D. Rockefeller, for the purpose of medical research. The Institute has been generously endowed by Mr. Rockefeller through a series of gifts which have from time to time provided for its growing needs. The Institute also administers a legacy from the late Henry Rutherford for the promotion of cancer research.

RUTGERS UNIVERSITY, New Brunswick, N. J.

Cook-Voorhees Fund. Established 1929, by Dr. Jacob G. Lipman, Dean of the College of Agriculture in memory of Dr. George H. Cook and Dr. Edward B. Voorhees. Raised by special contributions. For research in soil science. Capital, $29,500. Annually available, $1475.

ST. LOUIS SOCIETY FOR THE BLIND, 231 Metropolitan Bldg., St. Louis, Mo.

Dana (Leslie) Medal for the Prevention of Blindness. Established 1925, by Leslie Dana of St. Louis, Mo., to increase interest in the prevention of blindness. Original amount, $1000. Present amount, $1500. Annually available, $50 for the medal. The selection of the recipient of the medal is made annually by the National Society for the Prevention of Blindness, but no announcement of the selection is made without approval of the Board of Trustees of the Dana Medal Fund. So far as practicable the award is made annually in the City of St. Louis at which time the recipient may address the St. Louis Society for the Blind and allied organizations.

SCIENCE SERVICE, 2101 Constitution Ave., Washington, D. C.

Although not primarily a research institution, Science Service contributes to the advancement of science through its investigations in seismology, cosmic phenomena, anthropology and archaeology. This combination of research and news activity has been especially successful in its earthquake reporting service conducted since 1925 with the cooperation of the leading seismological observatories, the U. S. Coast and Geodetic Survey and the Jesuit Seismological Association. During a typical year more than thirty earthquakes are located and reported. In the fields of anthropology and archaeology, competent investigators are sent to alleged archaeological finds and reports made to Science Service for news and research purposes. Science Service gathers and distributes daily cosmic data reports, under the auspices of the American Section of the Union Radio Scientifique Internationale (International Scientific Radio Union). Daily reports are received from Mt. Wilson Observatory on sunspots, from the U. S. Coast and Geodetic Survey observatory at Cheltenham, Md., on magnetic conditions, from Smithsonian Institution on solar constant, from College of Agriculture and Mines, College, Alaska, on aurora, and from U. S. Bureau of Standards on Kennelly-Heaviside layer heights. These are transmitted by U. S. War Department radio to Science Service, assembled into an ursigram messaged and distributed by U. S. Navy radio throughout the world. Annual appropriations are made for these investigations.

SCOTT (JOHN) MEDAL, Board of Directors of City Trusts, 517 Lafayette Bldg., Philadelphia, Pa.

Scott (John) Medal Fund. Established 1816, by John Scott of Edinburgh, Scotland, for medals, with premiums, for useful inventions. Original amount, $4000. Present amount, $104,000. Annually available, $4500. Recommendations to Board of City Trusts are made by an Advisory Committee, of which Mr. Solomon M. Swaab, Fidelity-Philadelphia Trust Bldg., Philadelphia, Pa., is Secretary.

SEISMOLOGICAL SOCIETY OF AMERICA, Percy Byerly, Secretary, University of California, Berkeley, Calif.

American Association Fund. Established 1918, by the Grants Committee of the American Association for the Advancement of Science, for the investigation of earthquakes occurring on the Pacific Coast of North America. Occasional small grants are made for the study of individual earthquakes.

SMITHSONIAN INSTITUTION, Washington, D. C.

Arthur (James) Fund. Established 1931, by James Arthur, of New York, for investigation and study of the sun, and for a series of lectures to be known as the "James Arthur Annual Lecture on the Sun." Capital, $46,000. Annually available, income.

Endowment Fund. Established 1846, for the increase and diffusion of knowledge among men. Original amount, $508,318. Present amount, $1,828,773. Grants are made from the income of part of this fund from time to time, to scientific investigators.

Hanson (Martin Gustav and Caroline Runice) Fund. Established 1933, by Adolph M. Hanson, to accomplish or aid in accomplishing some scientific work of the Institution, preferably in chemistry or in medicine. Present amount, $1027. Work under fund not yet initiated.

Hodgkins Fund. Established 1891, for the increase and diffusion of more exact knowledge in regard to the nature and properties of atmospheric air in connection with the welfare of men. Original amount, $100,000. Annually available, $6000.

Hodgkins Gold Medal. Established 1893, for important contributions to the knowledge of the nature and properties of atmospheric air, or for practical applications of existing knowledge to the welfare of mankind. Value of medal, about $250.

Langley Medal. Established 1908, for specially meritorious investigations in connection with the science of aerodromics and its application to aviation. Value of medal, about $250.

Rollins (Miriam and William) Fund. Established 1932, by Miriam W. and William H. Rollins, for researches in connection with physics and chemistry. Capital, $58,000. Annually available, income after death of a surviving beneficiary.

SOCIAL SCIENCE RESEARCH COUNCIL, 230 Park Ave., New York, N. Y.

Grants-in-Aid of Research in the Social Sciences. Established 1927, by Laura Spelman Rockefeller Memorial. Since 1929 carried on by Rockefeller Foundation. The purpose is to assist in the completion of social research projects already well underway. Annually available, $25,000. Applicants must be citizens of the United States or Canada who have demonstrated their capacity for productive social research by published works. Applications must be filed on forms supplied by the Grants-in-Aid Secretary before February 1st.

SOCIETY OF AUTOMOTIVE ENGINEERS, INC., 29 West 39th St., New York, N. Y.

Manly Memorial Medal. Established 1928, through contributions of interested members in honor of the late Charles Matthews Manly. Awarded annually to the author of the best paper relating to theory or practice in the design or construction of, or research on, aeronautic power-plants or their parts or accessories which shall have been presented at a meeting of the Society or any of its Sections during the calendar year. Papers shall be judged primarily for their value as new contributions to existing knowledge of the aeronautic art. Judgment shall be based upon the value of the paper itself as such an original contribution, not upon the value of some mechanical development or invention already known which the paper may describe. Original amount, $8268. Present amount, $6828. Annually available, $260.

Wright Brothers Medal. Established 1927 (first award in 1928) to honor the first successful constructors and operators of heavier-than-air flying equipment and to encourage the presentation before the Society of the results of new development in the form of engineering papers. Awarded annually to the author of the best paper on aerodynamics or structural theory or research, or airplane design or construction, which shall have been presented at a meeting of the Society or any of its Sections during the calendar year. Papers shall be judged primarily for their value as new contributions to existing knowledge of the aeronautic art. Judgment shall be based upon the value of the paper itself as such an original contribution, not upon the value of some mechanical development or invention already known which the paper may describe. Annually available, $210.

The Society participates in the award of the following:

Daniel Guggenheim Medal. *See* Guggenheim (Daniel) Medal Fund, Inc.

SOCIETY OF CHEMICAL INDUSTRY, AMERICAN SECTION, Foster Dee Snell, Secretary, 305 Washington St., Brooklyn, N. Y.

Chemical Industry Medal. Established 1933. Awarded annually to a person making a valuable application of chemical research to industry. Primary consideration given to applications in the public interest. This medal replaces the Grasselli Medal, which has been discontinued.

Perkin Medal. Established 1906, for the most valuable work in applied chemistry.

SOCIETY OF ECONOMIC GEOLOGISTS, Guyot Hall, Princeton, N. J.

Penrose Medal. Established 1923, by R. A. F. Penrose, Jr., for unusually good work in the earth sciences. Awarded at intervals of usually not less than three years by the Council of the Society. Original amount, $2000. Present amount, $2300.

SOCIETY FOR EXPERIMENTAL BIOLOGY AND MEDICINE, College of the City of New York, New York, N. Y.

The Society has a fund of approximately $15,000 used for publication of the Society's journal. It is hoped that in the future this fund might be used for the furtherance of research in biology and experimental medicine. This is known as the Meltzer Endowment Fund.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS, 29 West 39th St., New York, N. Y.

Endowment Fund. Established 1914, for scholarships, prizes, research work, etc. Original amount, $12,560. Present amount, $132,109.

SOCIETY OF THE SIGMA XI, Professor Edward Ellery, Secretary, Union College, Schenectady, N. Y.

Grants. Established 1921, by subscriptions for grants in aid of research. Amount varies from $1000 to $3000 a year. Open to men and women for research in the United States or abroad. Applications should be filed with the Secretary before May 1st.

SOCIETY OF THE SIGMA XI, VIRGINIA CHAPTER, University of Virginia, University, Va.

President and Visitors Research Prize of $100. Established 1925, by Hollis Rinehart, to encourage scientific research at the University of Virginia. The prize of $100 in gold is awarded each year for the best piece of original investigation published by a professor or student of the University, the judges of the papers being appointed by the National President of the Society of Sigma Xi.

STANFORD UNIVERSITY, Stanford University, Calif.

Bacteriological Research. Established 1921, for miscellaneous research work within the department. Annually available, $3300.

Co-operative Test Fund, for Department of Psychology. To defray cost of devising objective examination methods in field of psychology. Available, $500.

Fluid Research Fund in the Medical Sciences. Established 1930, by Rockefeller Foundation. Available, 1930-31, $20,000; 1931-32, $25,000; 1932-33, $20,000, 1933-34, $15,000; 1934-35, $10,000; 1935-36, $5000.

Food Research Institute of Stanford University. Established 1921, for the intensive study of the problems of production, distribution and consumption of food, $700,000 provided by Carnegie Corporation of New York to be spent over a period of ten years. $750,000 additional grant for endowment received in 1932 with supplementary annual grants of $25,000 in 1933, $20,000 in 1934, $15,000 in 1935 and $10,000 in 1936.

Fund for Physics, Chemistry, Mathematics and Biology Departments. Established 1927, by General Education Board, for maintenance of work in these departments. $10,000 available in 1933-34.

Fund for Support of Project on Independent Study. Established in 1931 by the General Education Board. Present amount, $7692 with supplemental award of $20,000 for 1933-34.

Glikburg (Emilie) Memorial Fund. Established in 1931. The income to be used for research in medical sciences. Available annually, approximately $100.

Great Western Power Company and Pacific Gas and Electric Company. Grant of $5000 by each to Harris J. Ryan High Voltage Laboratory for experimental transmission line. Present amount, $4168.

Gregg (Wellington) Fund. Established 1920, by Roy H. Bishop, *et al,* for investigation of Bright's disease. Present amount, $285.

Guggenheim (Daniel) Fund for Promotion of Aeronautics. Established 1927, by Daniel Guggenheim Foundation, for the study of aeronautics. Original amount, $195,000. Annually available, $15,000 for ten years.

Holweger (Lieutenant Charles P.) Fund, for investigation of Bright's disease. Established 1933, by Dr. Thomas Addis. Available, $4648.

Hydro-Biological Survey of Monterey Bay. Established 1929-30 by the State of California Division of Fish and Game. Available, $2540.

National Electric Light Association Insulator Test Fund. Established 1920, for experimental work on suspension insulator deterioration and thermal fatigue tests. Present amount, $1938.

National Research Council. Grants have been made as follows: $1000 per annum, beginning 1931, for research in chemistry; $7000 for sex research in 1933-34; $900 for work on the effects of intense soft x-rays on micro-organisms; $417 for study of a balanced filter method of x-ray analysis and the Compton effect.

Research Committee. The committee makes grants to members of the faculty for study of various research problems. Annually available, $4000.

Rockefeller Foundation. Grant of $200,000 from September 1, 1932 to August 31, 1937 for research in the social sciences.

Somers (Mrs. Mary Hooper) Medical Research Fund. Established 1928, by Mrs. Somers, for research in encephalitis. Present amount, $5513.

Stanford (T. W.) Endowment for Psychology and Psychic Investigation. Established 1913, by Thomas Welton Stanford. Original amount, $513,901. Annually available, $30,000.

Stanford (T. W.) Fund for Psychic Investigation. Established 1911, by Thomas Welton Stanford, for psychic investigation. Original amount, $50,000. Annually available, $2500.

Study of the Psychology of Later Maturity. Carnegie Corporation of New York grant established in 1931. Available, $1441.

Vibration Research Fund for School of Engineering. Established 1926, by anonymous donor, for experimental studies on the effect of earthquake shocks on buildings. Present amount, $4075, supplemented by $2500 gift in 1931 from Research Corporation.

STATE INSTITUTE FOR THE STUDY OF MALIGNANT DISEASE, Buffalo, N. Y.

While there are no special funds set apart for research, the Institute is maintained for the purpose of research and treatment of malignant disease. The appropriation is made annually by the State of New York and amounts to about $250,000.

STATEN ISLAND INSTITUTE OF ARTS AND SCIENCES, Public Museum, Staten Island, N. Y.

Natural Science Fund. Established 1931, by William T. Davis, to be used exclusively for natural science purposes. Original amount, $2000. Present amount, $3125. Annually available, about $100.

SWARTHMORE COLLEGE, Swarthmore, Pa.

Lippincott (Joanna) Fund for Astronomical Research. Established 1924, by Joanna Lippincott. Original amount, $25,000. Present amount, $55,000. Annually available for research, $2750.

TANNERS' COUNCIL OF AMERICA, 41 Park Row, New York, N. Y.

Foundation of the Tanners' Research Laboratory. $22,000 is appropriated annually by members of the tanning industry for the maintenance of the Laboratory. The Foundation now has $45,500 in the form of an endowment, but the income from this will not be available until the principal sum has been increased, the present goal being $1,000,000.

TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY, 122 East 42nd St., New York, N. Y.

Gold Medal. Established 1916, to be given to an individual for an outstanding contribution to the technical development of the pulp and paper industry. The candidate is selected by an Awards Committee of the Association and unanimous approval of the Executive Committee is required. Two medals may be given each year.

TECHNICAL SOCIETY OF PHILADELPHIA, 2315 North Broad St., Philadelphia, Pa.

Clamer (Francis J.) Medal. Established by Francis J. Clamer under terms of will probated May, 1927, in recognition of the most distinguished achievement in the field of metallurgy. Capital, $1000. Annually available, $60, less Trust charges. The Fund is handled by the National Bank of Germantown and Trust Co., subject to orders from the Board of Directors of the Technical Society of Philadelphia.

TENNESSEE, UNIVERSITY OF, Knoxville, Tenn.

Engineering Experiment Station. Established 1923, for research in engineering. Annually available, $1500.

THOMPSON (ELIZABETH) SCIENCE FUND, A. C. Redfield, Secretary, 20 Divinity Ave., Cambridge, Mass.

Thompson (Elizabeth) Science Fund. Established 1885, by Mrs. Thompson, of Stamford Conn., for the advancement and prosecution of scientific research in its broadest sense. Capital, $25,000. Annually available, $1000. Grants made at meetings held in November, February and May.

TOLEDO HOSPITAL, Toledo, Ohio.

Research Funds, establishel 1930, by Frank C. Collins and Mrs. George H. Pomeroy, to further medical research. Original amount, $5000. Present amount, $16,000. Interest on capital plus contributions during the year average $1000. No grants are made.

TROPICAL PLANT RESEARCH FOUNDATION, 1086 North Broadway, Yonkers, N. Y.

Tropical Plant Research Foundation. Established 1924, to promote research for the advancement of knowledge of the plants and crops of the tropics; to conduct investigations in plant pathology, entomology, plant breeding, botany and forestry, horticulture and agronomy, and to publish the results thereof; and to establish and maintain such temporary or permanent stations and laboratories as may be necessary for the accomplishment of these objects. Supported by funds contributed by organizations and individuals interested in its several research projects.

TRUDEAU FOUNDATION, Saranac Lake, N. Y.

Trudeau Foundation. Established 1916 by numerous donors, for research and teaching in tuberculosis. Original amount, $250,000. Present amount, $544,228. Annually available, $19,185 (1934-35 fiscal year). Application for grants should be sent to Edward R. Baldwin, M. D., Director, Saranac Lake, N. Y. The Trudeau Foundation also supports the Medical Library and Statistical Department of the Sanatorium while partly financing the Research and Clinical as well as the Saranac Laboratories.

TUFTS COLLEGE, Tufts College, Mass.

Charlton (Earle P.) Gift for Research. Established 1931, by Earle Perry Charlton, for medical research. Capital, $391,347. This fund is not in the hands of the Trustees of Tufts College but is in the custody of a local bank which has full control of the principal and distributes the income at its discretion. Temporarily the income is withheld.

TULANE UNIVERSITY, New Orleans, La.

Dennery (Harry) Research Fund. Established 1928, by Mrs. Harry Dennery, in memory of her husband, for research in the School of Medicine. Original amount, $2000. Present amount, $2100. Annually available, $105.

Geiger Medal. Established 1928, by Dr. and Mrs. J. C. Geiger of San Francisco, California, for a gold medal to be awarded annually to the senior or graduate student in Tulane University who writes the best thesis on a public health problem that is of importance to either the Southern States or countries contiguous to them. The problem must be of sufficient importance in the opinion of the Committee on the award to justify granting it.

Harrod Fund for Cancer Research. Established 1917, by Mrs. Benjamin Morgan Harrod, for the investigation of the cure of cancer. Original amount, $5000. Present amount, $5000. Annually available, $250.

Hart (Violet I.) Fund. Established 1933, by Mike S. Hart, to provide an award known as the Rudolph Matas Award in Vascular Surgery to be made to the North American surgeon who has contributed outstanding work in vascular surgery. Capital, $1000. Annually available, $50.

Middle American Research Fund. Established 1924, by an anonymous donor, for advanced research into the history, archaeology, botany, the natural resources and products of Mexico, the Central American republics and the West Indies. Its aim is to gather and disseminate data on these countries, and to further friendly relations between the United States and its neighbors to the south. Annually available, $15,000.

Newman (Edgar) Research Fund. Established 1928, by an anonymous donor, for research in the School of Medicine. Original amount, $5000. Present amount, $5290. Annually available, $264.50.

Schwartz (David Trautman) Research Fund. Established 1922, by Mr. and Mrs. Leon E. Schwartz, with subsequent gifts, for research work and fellowship purposes in the School of Medicine. Original amount, $20,000. Present amount, $23,100. Annually available, $1135.

UTAH, UNIVERSITY OF, Salt Lake City, Utah.

Engineering Experiment Station. Appropriation made biennially by the State Legislature, for mining and metallurgical research. Annually available, $1600.

The University makes more or less miscellaneous appropriations from the general budget to cover specific researches. Available in 1933, $4100.

VANDERBILT UNIVERSITY, SCHOOL OF MEDICINE, Nashville, Tenn.

Rockefeller Foundation Fund. Established 1932 by the Division of Medical Sciences of the Rockefeller Foundation for research over a period of eight years. Original amount, $250,000.

A certain proportion of the departmental budgets is available for research.

VASSAR COLLEGE, Poughkeepsie, N. Y.

Stillman Research Fund. Established 1931 by the Orange and Dutchess County Garden Club, for the use of Professor Edith Roberts of the department of Botany, Vassar College, for research in native plants. Capital, $2000. Annually available, $80.

Whitney (Mary W.) Fund for Astronomical Research. Established 1921-22 and 1925, by Mary W. Whitney and the Trustees of Vassar College. Preferably for independent work of the Observatory, such as computing, publication, etc., but at the disposal of the Director for such use as she deems best. Capital, $5000. Annually available, income.

VILLANOVA COLLEGE, Villanova, Pa.

Mendel Medal. Established 1929; conferred annually by vote of the Faculty and Trustees on a Catholic who has signally advanced the cause of science.

VIRGINIA ACADEMY OF SCIENCE, E. C. L. Miller, Secretary, 12th and Clay Sts., Richmond, Va.

Research Endowment Fund. Established 1926 by subscriptions from more than 30 donors, for the encouragement and development of scientific research in Virginia. Original amount, $9100. Annually available, between $500 and $600. Administered by a Research Committee and granted only to members of the Academy.

Research Prize. Established 1925 for three years by an anonymous donor, to stimulate productive work in Virginia. Since that time, continued from the income of the Research Endowment Fund. Awarded at the annual meeting for a paper presented by a member of the Academy that is adjudged particularly meritorious.

WAGNER FREE INSTITUTE OF SCIENCE, Philadelphia, Pa. Carl Boyer, Director.

Department of Chemistry Endowment. Established 1909, by Henry Leffmann, for research in chemistry. Original amount, $6000. Present amount, $8497, two-thirds of the income of which only is available for research. Annually available, $317. Grants are made to persons chosen by the Board of Trustees.

Leffmann (Henry) Research Fund. Established 1930, by deed of trust from Henry Leffmann, for research in chemistry. Original amount, $19,261. Present amount, $17,655. Annually available, approximately $892 (income received from trust funds of which principal is not controlled by the Institute). Grants are made to persons or institutions chosen by the Board of Trustees.

WASHINGTON, UNIVERSITY OF, Seattle, Wash.

Gatzert (Bailey and Babette) Foundations for Child Welfare. Established 1910, for the purpose of conducting a laboratory for the mental and physical examination of children to determine their individual defects and aptitudes and, in accordance with the results of the examination, to suggest the best means of education and treatment; to assist in establishing the child welfare agencies and child study laboratories throughout the State, and to carry on research in child psychology. Original amount, $30,000.

McDermott (Alice) Memorial Fund. Established by the late Mrs. Josephine P. McDermott, for research work in or in connection with the University of Washington, tending to promote the prevention of tuberculosis, and for the purchase of radium for research work in connection with disease of or actual treatment thereof. Original amount, $100,000.

WASHINGTON UNIVERSITY, St. Louis, Mo.

Ball (E. Arthur and Frank E.) Fund. For developing the Division of Physics in the Department of Oto-Laryngology, $60,000 has been given for a period of five years beginning with 1930-31. Annually available, $12,000.

Commonwealth Fund of New York Fund. For research in trachoma over a period of five years, beginning 1930-31. Available for 1933-34, $32,160.

General Education Board Fund. For Department of Surgery. For 1933-34, $10,000; for 1934-35, $5000.

Industrial Engineering and Research Fund. For 1933-34, $2825.

International Cancer Research Foundation Fund. For research in cytology. $1800 over three years beginning 1933-34. Annually available,

$600. For research in pathology. $10,000 over a period of two years beginning 1933-34. Annually available, $5000.

Macy (Josiah, Jr.) Foundation Fund. For research in cytology (arteriosclerosis in monkeys). For 1933-34, $2500.

Mallinckrodt (Edward, Jr.) Fund. For research in biochemistry. For 1933-34, $750.

Monsanto Chemical Works Fund. For research in bacteriology (on germicidal products). For 1933-34, $2400.

National Research Council Fund. For virus research in cytology; for 1933-34, $500. For research in otolaryngology; for 1933-34, $1600.

Niedringhaus (Mrs. Helen J.) Fund. For research in neurological surgery. For 1933-34, $2500.

Rockefeller Foundation Fund. For research in cytology on virus diseases. $15,000 maximum over a period of four years, beginning May 1, 1932. Annual amount not to exceed $5000. For research in neuro-physiology, for a period of five years, beginning September 1, 1933; for 1933-34, $11,700; not more than this amount to be expended any year. Fluid research in various scientific departments, $240,000 over a period of seven years, beginning 1930-31; for 1933-34, $40,000.

Surgical Research fund. For 1933-34, $1000.

WESLEYAN UNIVERSITY, Middletown, Conn.

The Departments of Physics and Chemistry have funds for equipment; research projects are thus assisted but no appointments made from the fund's income.

WESTERN SOCIETY OF ENGINEERS, 205 West Wacker Drive, Chicago, Ill.

Chanute Medal. Founded by Octave Chanute. Three bronze medals are awarded annually for the best papers on civil, mechanical and electrical engineering presented by members during the year. Capital, $1000.

Commission of Washington Award. Established 1917, by Past President Alvord of the Western Society of Engineers, to be presented annually to an engineer whose work in some special instance, or whose services in general have been noteworthy for their merit in promoting the public good. The award is made by a committee composed of nine representatives from this Society and two each from the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers, and the American Institute of Electrical Engineers.

Hunt (Robert W.) Award. Established 1920, by Robert W. Hunt, Past President of the Society, to be awarded for the best paper pertaining to the manufacture of iron and steel products or their subsequent fabrication, contributed during the calendar year by a member of the Society, not more than 35 years of age. Original amount, $5000. Annually available, approximately $225.

The Society participates in the award of the following:

Alfred Noble Prize. *See* American Society of Civil Engineers.

WIEBOLDT FOUNDATION, 106 South Ashland Ave., Chicago, Ill.

Wieboldt Foundation. Established 1921, by Mr. and Mrs. William A. Wieboldt, " to dispense charity." Funds are, for the most part, given to existing agencies for building purposes, current expense, research or other purposes. Original amount, $5,000,000. Present amount, $3,000,000. Income available.

WISCONSIN, UNIVERSITY OF, Madison, Wis.

Bowman (Jonathan) Memorial Fund. Established in 1933 by bequest of Miss Jennie Bowan. The income of the capital sum of between $300,000 and $400,000 is to be used for medical and surgical research in the study of cancer. The fund is left in trust to the First Wisconsin Trust Company of Milwaukee and the income therefrom is to be expended under the direction of the Board of Regents of the University. The will had not been officially proved on April 9, 1934.

University Research Fund. Established 1919, to promote research projects in the University. Annually available, $35,000. For staff of University only.

Wisconsin Alumni Research Fund. Established 1927. Allotment for 1933-34, $120,000. For staff of University only.

General appropriation to College of Engineering, for research. Annually available, $22,440.

WISCONSIN ARCHAEOLOGICAL SOCIETY, Milwaukee, Wis.

Lapham Medal. Conferred upon members and other anthropologists from time to time, for distinguished service in American anthropological research. Eleven medals have been awarded to date. Named in honor of Dr. Increase Allen Lapham, pioneer Wisconsin archaeologist.

WYOMING HISTORICAL AND GEOLOGICAL SOCIETY, Wilkes-Barre, Pa.

Hayden Lecture Fund. Established prior to 1915, by Rev. Horace E. Hayden, for an honorarium on a scientific lecture. Original amount, $1500. Present amount, $1500. Annually available, $75.

Miner (Charles Abbott) Fund. Established 1909, by the family of Charles Abbott Miner, for the purchase of geological books and specimens, lectures, etc. Present amount, $1000. Annually available, $50.

YALE UNIVERSITY, New Haven, Conn.

Chittenden (Russell H.) Fund. Established 1915, for research in physiological chemistry. Original amount, $4000. Present amount, $5500. Annually available, $220.

Dana Fund, for original investigation in geology. Annually available, $500.

Fitkin (Abram E.) Fund. The purpose of this fund is the study of children's diseases and child life. Original amount, $1,000,000. One-half of the original gift was used for a building dedicated to the care of children and the balance is an endowment for the Department of Pediatrics.

Forest Production Research Fund. Established by anonymous donor, 1923, for investigation in forest production. Original amount, $100,000. Annually available, $4000.

Hadley University Fund, for research in general. Original amount, $1030. Annually available, $41.

Institute of Human Relations. An endowment to support specific work. Original amount, $1,000,000.

Institute of Psychology. Established 1923, by Laura Spelman Rockefeller Memorial, for research in psychology; now continued by the Rockefeller Foundation. Annual grant, $40,000. In addition to this, the Rockefeller Foundation has made an annual grant of $40,000 for anthropoid research and the National Research Council annual grants of approximately $7500, for sex research.

Loomis Fund. Established 1889, for research in astronomy. Original amount, $312,415. Present amount, $313,865. Annually available, $12,550.

Loomis (Francis E.) Fund. Established 1911, for research in the departments of anatomy, physiology and pharmacology. Present amount, $20,000. Annually available, $800.

National Tuberculosis Association Fund. Established 1924, by the Association, for research in tuberculosis. Annually available, $6200.

Organic Chemistry Research Fund. Established 1918, for research in organic chemistry. Original amount, $600. Present amount, $3300.

Plant Pathology Research. Established 1926, for study of decay in trees. Annual grant, $5600.

Psycho-Clinic. Established 1926, by Laura Spelman Rockefeller Memorial; now continued by Rockefeller Foundation, for child research. Annual grant, $35,000.

Ridgway (Gertrude Knight) Memorial for Dr. George H. Knight, Yale 1877. Established 1923, by Mrs. George H. Knight, for bettering conditions in nervous and mental diseases, especially that form of it resulting in epilepsy and feebleminded conditions. Present amount, $81,000.

Silliman (Hepsa Eli) Fund. Established 1901, a certain portion of which is applicable to scientific research. Original amount, $94,741.

Sloane (Henry T. and William D.) Funds. Established 1919, for the study of physics and for research assistants in the new Sloane Physics Laboratory. Present amount, $125,000.

Sloane (Thomas C.) Fund. Established 1891, for the study of physics in the Sloane Physics Laboratory. Present amount, $90,000.

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BULLETIN
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NATIONAL RESEARCH COUNCIL

NUMBER 96

SELECTED TOPICS IN ALGEBRAIC GEOMETRY—II

Supplemental Report of the Committee on Rational Transformations

VIRGIL SNYDER, AMOS H. BLACK AND
LEAMAN A. DYE

PUBLISHED BY THE NATIONAL RESEARCH COUNCIL
OF
THE NATIONAL ACADEMY OF SCIENCES
WASHINGTON, D. C.
1934

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Supplemental Report of the Committee on Rational Transformations[1]

VIRGIL SNYDER, AMOS H. BLACK AND
LEAMAN A. DYE

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PREFACE

Shortly after the appearance of Bulletin 63, Selected Topics in Algebraic Geometry, in 1928, the wish was generally expressed that provision should be made for a supplementary report on the same general lines, to cover the decade following the period included in the Report. In consequence of this demand, the Committee was continued. The admirable work of Berzolari in the Encyklopädie der mathematischen Wissenschaften: Algebraische Transformationen und Korrespondenzen has so nearly covered the transcendental theory and the mapping of algebraic surfaces that they have not been given a place in the present report. On the other hand, the mapping of curves and of systems of curves has been done in greater detail and wider inclusion of sources than was possible in the work of Berzolari. This was done mostly through the competent cooperation of Dr. L. A. Dye. Similarly, properties of surfaces, not always coming under the caption of rational transformations, have been collected and arranged by Dr. Amos H. Black. The Committee wishes to thank both of these men; by their contributions the value of the report has been materially increased.

While the other chapters have been largely the work of one member, it was with the assistance and support of the others; circumstances have been such as to prevent a more intensive cooperation.

THE COMMITTEE.

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Abh. Hamb. Sem.: Abhandlungen aus dem mathematischen Seminar der Hamburgischen Universität.
Acta Math.: Acta Mathematica.
Acta Soc. Helv.: Actes de la Société Helvetique des sciences naturelles.
Am. J.: American Journal of Mathematics.
Am. Math. Month.: American Mathematical Monthly.
Am. M. S. Bull.: American Mathematical Society, Bulletin.
Am. M. S. Trans.: ————————, Transactions.
Amst. K. Ak. Wet. Verh.: Koninklijke Akademie van Wetenschappen te Amsterdam, Verhandelingen.
Amst. K. Ak. Wet. Versl.: ————————, Verslag.
Amst. K. Ak. Wet. Proc.: ————————, Proceedings.
Anais de Soc. Porto: Anais de la Faculte des sciences, Porto.
Ann. di Mat.: Annali di Matematica Pura ed Applicata.
Ann. di Pisa: Annali della R. Scuola normale superiore di Pisa.
Ann. Éc. Norm.: Annales scientifiques de l'École Normale Supérieure, Paris.
Ann. of Math.: Annals of Mathematics.
Ann. Soc. Pol.: Annales de la Société Polonaise de mathématique.
Arch. Néerl.: Archives Néerlandaises des sciences exactes et naturelles.
Berlin M. G. Math.: Sitzungsberichte der Berliner mathematischen Gesellschaft.
Berlin Monatsber.: Berlin. Preussische Akademie der Wissenschaften. Monatsberichte (to 1881).
Berlin Sitzungsber. ————————. Sitzungsberichte (since 1881).
Bol. Congr.: Atti del Congresso internazionale dei Matematici, Bologna, 1928.
Boll. d. U. M. It.: Bollettino della Unione Matematica Italiana.
Brux. Bull.: Bruxelles. Académie Royale de Belgique. Bulletin.
Buch. Bull.: Bulletin de mathématique et de physique pure et appliquées de l'École polytechnique de Bucharest.
Bull. Ac. Romaine: Bulletin mathématique de la Société Romaine des Sciences.
Bull. Intern.: Bulletin international de l'Académie de Bôhème.
Bull. Sci. M.: Bulletin de sciences mathématiques. (Darboux).
Cal. Univ. Publ.: Publications of the University of California.
Camb. Ph. Soc. Proc.: Cambridge Philosophical Society. Proceedings.
Časopis: Časopis pro Pěstováni Mathematiky a Fisiky.
Cat. Acc. Gio. Atti: Atti della Accademia Gioenia di Scienze Naturali in Catania.
Comm. Helv. Math.: Commentarii Mathematici Helvetici.
C. R.: Comptes Rendus. Académie des sciences de l'Institut de France. Paris.
Deutsche Math.-Ver.: Deutsche Mathematiker-Vereinigung. Jahresbericht.
Edinb. M. S. Proc.: Edinburgh Mathematical Society. Proceedings.
Enseign. Math.: Enseignment mathématique.
Gaz. Mat. Buk.: Gazeta matematica. Bukarest.
Giorn. di Mat.: Giornale di Matematiche.
Hamb. M. G. Mitt.: Hamburg. Mathematische Gesellschaft. Mitteilungen.

Heidelb. Sitzber: Sitzungsberichte der Heidelberger Akademie der Wissenschaften. Mathematisch-naturwissenschaftliche Klasse.
Ind. M. S.: Indian Mathematical Society. Journal.
Isis: Isis.
J. de Math.: Journal de mathématiques pures et appliquées. Liouville.
J. Éc. Polyt.: Journal de l'École polytechnique. Paris.
J. f. Math.: Journal für die reine und angewandte Mathematik.
Jap. M. J.: Japanese Journal of Mathematics.
Jour. Hirosh Univ.: Hiroshima University Journal of Science. Section A.
Lening Ann. Ist. Polyt.: Izvestija Teknologiceskogo Instituta imeni Leningrad kogo Seveta (Annales de l'Institut polytechnique de Leningrad.)
Liège S. R. Mém.: Liège. Société royale des sciences. Mémoires.
Lomb. Ist. Mem.: Reale Istituto Lombardo di Scienze e Lettere. Milano. Memorie.
Lomb. Ist. Rend.: ——————. Rendiconti.
London M. S. Proc.: London Mathematical Society. Proceedings.
London M. S. J.: ——————. Journal.
London R. S. Trans.: Royal Society of London. Philosophical Transactions.
Math. Ann.: Mathematische Annalen.
Math. Zschr.: Mathematische Zeitschrift. Berlin.
Mathesis: Mathesis. Belgium.
Mem. Acc. It.: Reale Accademia d'Italia. Memorie della Classe di Scienze Fisiche, Matematiche e Naturali.
Mem. Univ. Jap.: Memoirs of the Faculty of Science and Agriculture, Taihoku Imperial University.
Mess. of Math.: Messenger of Mathematics.
Monatsh. f. Math.: Monatshefte für Mathematik und Physik.
Münch. Ber.: München Königliche Bayerische Akademie der Wissenschaften. Mathematisch-physikalische Klasse. Sitzungsberichte.
Nap. R. A. Atti: Napoli. Reale Accademia delle Scienze, Fisiche e Matematiche. Atti.
Nap. R. A. Rend.: ——————. Rendiconti.
Nieuw Arch.: Nieuw Archief voor Wiskunde Uitgegeven door het Wiskundig Genootschap.
Nieuw Tidschr.: Nieuw Tijdschrift voor Wiskunde.
Norske Vid. Ak. Avh.: Avhandlinger utgift av det Norske Videnskaps Akademie.
Note e Eserc. Cat.: Note ed esercitazioni matematiche.
Nouv. Ann.: Nouvelles annales de mathematiques.
Pad. Sem. Rend.: Rendiconti del Seminario matematico della Reale Università di Padova.
Pal. Circ. Mat.: Palermo. Circolo Matematico. Rendiconti.
Per. di Mat.: Periodico di Matematiche.
Phil. Mag.: Philosophical Magazine.
Prac. mat. fiz.: Prace matematyczne fizyczne. Warsaw.
Prag. Ber.: Prager Abhandlungen der königlich Böhmischen Gesellschaft der Wissenschaften. Sitzungsberichte.
Ras. di mat.: Rassegna di matematica e fisica. Rome.
Rec. Math.: Receuil mathématique. Moscow.
Rev. de Math. Spec.: Revue de mathématiques speciales (1890-1914).
Rom. Acc. L. Mem.: Roma. Reale Accademia dei Lincei. Memorie.

Rom. Acc. L. Rend.: ——————. Rendiconti.

Roum. Ac. Bull.: Bulletin de l'Académie Roumaine.

Sächs. Ber.: Berichte über die Verhandlungen der Sächsischen Akademie der Wissenschaften zu Leipzig.

Soc. M. F. Bull.: Société mathématique de France. Bulletin. Paris.

Tôhoku M. J.: Tôhoku Mathematical Journal.

Tôhoku Sc. R.: Tôhoku Imperial University. Science Reports.

Torino Mem.: Torino. Reale Accademia delle Scienze. Memorie.

Toulouse Ann.: Toulouse. Faculté des sciences de l'Université. Annales.

Univ. Masaryk Pub.: Publications de la Faculté des Sciences de l'Université Masaryk.

Wash. Nat. Ac. Sc. Proc.: Washington, National Academy of Sciences. Proceedings.

Wien. Ber: Wien. Kaiserliche Akademie der Wissenschaften. Mathematisch-naturwissenschaftliche Klasse. Sitzungsberichte.

Wis-en Nat. Verh.: Wis-en Natuurkundige Verhandlingen.

Zent. blatt f. Math.: Zentralblatt für Mathematik und ihre Grenzgebeite.

Zurich Congr. Int.: Verhandlungen des internationalen Mathematiker-Congresses, Zurich, 1932.

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CHAPTER I

CURVES AND RULED SURFACES

VIRGIL SNYDER

1. Rational curves. (*a*) *Cubics.* Condition for contact of the plane rational cubic can be expressed parametrically. For ordinary intersection with a C_n each symmetric function S_t appears to the first power. For contact, powers higher than the first appear (Griffiths[61]). Further properties of involutions on the plane rational cubic can be expressed by means of a pencil of conics. One group (on a composite conic) consists of collinear points (de Vries[155]).

A problem in closure, defined by the first tangential point of a given point on a rational cubic is solved by Allen.[3] If $x=3t^2$, $y=3t$, $z=t^3+1$ is the parametric representation, then the nth tangential will coincide with the given point $t=-t^{(-2)^n}$ and $2^n-4\equiv 0 \pmod{12}$. If n is odd, $2^n+1\equiv 0 \pmod{3}$. Further applications of involutions are given by Pomey.[111] Let a rational plane cubic curve be defined by a double point and six simple points, to find its point of inflexion.

The nodal cubic is also studied by Cattaneo.[19] The same author[21] discusses the circular conchoid. *See also* Campedelli[18] and Biggiogero.[13]

Given a rational space cubic by means of its plane projection, to find its osculating planes through a given point. The same procedure applies to plane quartic curves.

(*b*) *Quartics.* Properties of the tricuspidal quartic are obtained by quadratic transformation. The invariants are derived and covarient curves are obtained by Longhi.[80] Properties obtained from the method of generation without the use of transformations are given by Villa.[149] Contact conics, including those having two points of four point contact, were found by Joliffe.[70] That eight point contact of a conic is impossible except at a singular point was shown by Hilton and Green.[63] The polar properties expressed by means of an appropriate coordinate system are given by Rutter.[124] A generation of trinodal C_4 by means of two projective pencils of conics with three common base points is given by Deaux.[36] A quartic with an oscnode is rational. The condition that a C_4 has an oscnode is expressed as a binary relation, when the triangle of reference is suitably chosen (Neelley[102]). Moore and Neelley[96] derive the condition that a tacnodal or an oscnodal C_4 can be a plane section of a given quartic surface. Further properties are given by Neelley[103] with interpretations in hyperspace. James[69] corrects a statement in an earlier paper concerning involutions on a normal C_4. Further involutions of points on a trinodal C_4 are derived by de Vries.[156]

(*c*) *Curves of higher order.* Winger[161] discusses self-projective rational C_7. A C_4 in S_4 has seven trisecant planes in general position. When the planes are given, ten C_4 can be found meeting each in 3 points (Babbage[7]). Morton[100] discusses inscribed tetrahedra and other forms which fulfill one extra condition. Another representation of C_4 of S_4 is given by Semple[133]. A quadric primal of S_5 is mapped on S_4 and the points of V are interpreted as lines of S_3. Associated quartics are determined by the reciprocal transformation $x'_i = 1/x_i$.

Libois[78] derives conditions for rational C_6 in S_3. The C_6 may have $\infty^1 s_5$ (lines meeting it in five points) or one or none; in the latter case it must have six s_4 and lies on a cubic surface.

A rational C_5 of S_3 can be generated by various projective forms (Deaux[27]). A C_5 with two double points lies on a quadric cone, but has only one quadri-secant, thus correcting a statement made by Loria. Arnold[5] derives various binary relations between the rational C_5 of S_3 and the plane rational C_4, when the former lies on a quadric surface. James[68] provides algebraic machinery for correspondences on rational curves, with simple geometric applications.

Conditions for closure of polygons circumscribing one conic and inscribed in another were derived by Burnside.[15] It is a recurring equation of the form

$$(p_n - p_1)^2 p_{n-1} p_{n+1} = (p_n p - 1)^2.$$

If the point x describes a curve C, x' a curve C', then $\xi = x + ax'$ divides the line segment joining x, x' in a constant ratio. Consequences of this for various relations between x and x' are found by Papillon,[107] largely by differential methods.

Given a rational plane quintic with three cusps, it is possible to effect a classification of possible forms by means of the sequence of double points. Ten schemes are possible (Peterson[108]).

An elaborate study of involutions on rational curves was made by Pomey,[111, 112] by means of linear systems of transversal curves, with base points on the given curve. A large number of theorems is included. Among those already known, the proofs are different from those by which they were first established. Gambier[43, 44] discusses a generalization in which one of the conics is replaced by a curve of class m.

The condition that a binary f_4 shall be a line section of the Jonquières C_4 is given by Arnold.[4] The form must be apolar to the fundamental involution of the curve.

The rational C_5 was also studied by Siefert.[132] Further properties of the lemniscate were found by Marck.[87] Cattaneo[19] derives the line equation of a rational plane curve when the parametric form of the point equation is given.

A generalization of the theorem of Bertini, that the three principal chords of a rational C_4 of S_3 are concurrent, can be extended to rational curves in S_{2n+1} (Berzolari[12]). By means of stereographic projection of a quadric surface, polarity as to a quadric, various properties of circles, pencils and nets of circles is found by Biggiogero.[13]

The points of contact of an algebraic curve and its envelope are discussed at the points of higher multiplicity, by means of the methods of differential geometry (Gambier[44]). Colucci[24] extends parametric representation to the complex plane and applies it to the geometry of the circle. Many results already known are confirmed by this method.

Rindi[120] obtains relations among n points of a line, squares of first members of their equations. Vaidyanathaswami[145] expresses a rational normal curve C_n in terms of its quadratic manifolds without any use of transformations.

The generation of plane algebraic curves by means of points in the complex plane defined by $z=x+iy=f\left(\frac{\alpha+\lambda\beta}{\gamma+\lambda\delta}\right)$ is given by Abramesco.[1]

2. Correspondences. (*a*) *General.* A few extensions to correspondences between two one-dimensional carriers have been made but mostly to particular problems. If a geometric problem admits, in general, of no solution, then the existence of one solution in a special case implies the existence of an infinite number. If the existence of one solution implies the existence of an infinite number, then, in general, there is no solution. This is applied to space cubics touching four lines by Grace.[57] Thus Vaidyanathaswami[146] applies the general (m, n) correspondence to C_r in S_r. Elementary algebraic formulation. In a later paper the same author[147] applies the $(2, 1)$ case to circles. Apolarity is used. A third paper considers $(3, 2)$ correspondences on circles.[148] Emch[34] considers the symmetric (n, n) correspondences. Given $f(x, y)=0$, let $x=\lambda+\mu$, $y=\lambda\mu$, where λ, μ is the parameter pair of a point on a rational curve. Various problems in closure result. The principle is applied to the correspondence between the tangents of two plane curves, with a number of illustrative examples by Barce.[10]

Terracini[140] discusses the problem of the reducibility of the correspondence defined by a point P on a curve of S_4 and the residual points in which the osculating hyperplane meets the curve. In S_3 there are two cases; one is furnished by W-curves, in which one component may define a collineation, and those belonging to a linear complex. The asymptotic lines on ruled surfaces having two rectilinear directrices are always of the latter class. In S_2, if one component defines a collineation, every one must.

Geometrical applications of binary (n, n) correspondences expressed in the form $\Sigma a_i\lambda^{n-i}=0$, $\Sigma b_i\mu^{n-i}=0$, in which a_i, b_i are linear in point coordinates are discussed by Emch.[27] If $\phi(\lambda, \mu)=\phi(\mu, \lambda)=0$ is given, a $(1, n^2)$ transformation is defined in which $C_m(x)\sim\Gamma_{n^2m}(x)=0$. A Cremona I_6 in S_2 is also obtained in this way. Gambier[44] applies this and other principles to the intersection of two plane algebraic curves at a point k-fold on each. The derivation of k^2+m such points is partly synthetic and partly transcendental.

The coincidences of a multiple correspondence between the elements of two varieties is brought to a reduced form by Ursell.[144] The general formula was first derived by Lefschetz.[77]

A (2, 2) correspondence between the points of two planes may be periodic. The reduction of such cases to a canonical form has been made by Edwards[33]; *see also* Meyer.[92]

Applications of the theory of forms have been made by Moore,[98] Turnbull,[142] Piedvache[110] and McCoy.[86] Jonzon[74] gives a systematic analysis of the Cremona transformations under which particular elliptic and hyperelliptic curves remain invariant, thus supplying the details of the earlier work by Wiman; *see also* Baker[9] and Gherardelli.[49]

Applications of Zeuthen's formula for coincidences have been made by Marletta and by Brigaglia.[15]

Extensions to correspondence in hyperspace were done by Roth[122] and by James.[68, 69]

Applications to lines on quadrics were made by Sapienza and to congruences of lines by Hulin,[66] while Segre[129, 130] applies the principle to pairs of points of a given entity.

(*b*) *Cubics.* Ciani[23] proposes the canonical form $x_1^2x_2+x_2^2x_3+x_3^2x_1+2kx_1x_2x_3=0$ for the plane cubic curve.

Properties of the synthetic pencils of cubics obtained from the Hesse form and from its dual, without use of transformations, are given by Joliffe.[71, 72]

The base points of a pencil of plane C_3 were discussed by Emch.[35] A C_3 given by three asymptotes is discussed by Rao[116] and earlier by Durairajan.[30] Polarity as to a given plane C_3 is applied to furnish proofs of a number of theorems previously given without proof by Genoino.[48]

Triangles in-and-circumscribed to two cubic curves are unique unless some particular relation exists between the two given curves (Bell[11]).

The circular C_3 can appear as the envelope of a particular system of circles (Green and Prior [59]).

The general (2, 1) correspondence between two real variables was discussed by Purushottam.[114] Pencils of $|C_3|$ having 4 given points for common points of inflexion are studied by Turner.[148] They can be arranged into groups according to the number of imaginary basis points. The 24 triangles in-and-circumscribed to a general C_3 are discussed by Ogg [105] by methods partly algebraic and partly by means of elliptic functions. An equianharmonic C_3 is invariant under a certain G_{108} of Cremona transformations. The Hesse configuration on a plane C_3 is associated with desmic tetrahedra $(12_4, 16_3)$ (Mathews [90]). This is a generalization of Coble's checkerboard arrangement, further extended in.[91]

Pencils of equianharmonic curves were first constructed by Chisini [22] and further developed by Yerushalmy.[164, 165] Each curve of the pencil is invariant under the Cremona transformation $u'=u+a$, $[\omega^3=1]$. The pencil contained in a net through six points, vertices of two triangles in-and-circumscribed to a cubic ϕ are three fold perspective from the vertices of the third triangle of base points. Sets of points on C_3 with rational coordinates are treated by Logsdon.[79]

(*c*) *Quartic curves.* The bicircular C_4 can be expressed in terms of power coordinates. This is done in a new way by Wilson.[159] The entire system is invariant under inversion. A particular such curve is treated by D'Ocagne.[28] The tritangent circles of a circular C_4 are obtained by Richmond [117] by projecting a $C_6=F_3$, F_2 from a double point on F_3, simple on F_2. The C_4 obtained by the Geiser projection is studied from the stand point of its systems of bitangents by Blakey.[14] The C_4 with all real bitangents is further discussed by Du Val.[31] Systems of in-and-circumscribed triangles are constructed by Edge [32] and by Milne,[95] using the same method. The system of bitangents of the uni-nodal C_4 is further developed by Richmond,[118] without further use of transformations.

The $|C_6|:9P_2$ of Halphen are constructed by Godeaux by means of mapping an F_3 on S_2. Construct a conic touching a C_3 in three points and pass a pencil $|F_2|$ through it. Various particular cases are given by Godeaux.[51, 54, 55] Ogg [104] describes a Γ_{256} under which a C_4, $p=1$, of S_3 remains invariant, by means of elliptic parameters. Telling [138] discusses reality conditions for the rational quartic curves of S_3 by means of projections of the normal C_4 of S_4 upon S_3, and the dual operation.

(*d*) *Various curves.* Given a γ_k^m on $C_n^{(p)}$ of S_r, to determine the number of triads of points, such that each will belong to the same group of γ_k^m with the same multiplicity. The problem was solved by Longhi,[81] who made applications to ruled surfaces, circles and spheres.

If a curve C contains a complete g'_k, then C has a g_{n+k} containing a complete g_n^r, without a fixed residue. The necessary and sufficient condition that g_n^r be contained partially in g_{n+k} is that g'_k exists, but not a g'_{k-1} (Maroni [89]).

3. Linear series. Segre [128, 129] showed that continuous systems of plane curves exist belonging to every compatible set of solutions of Plücker's numbers; *compare* Crone [Acta Math. 2: 81-96 (1883)]. The postulate of Lefschetz is not always true. The virtual dimension δ' may not be the same as the effective dimension δ^*. The equality of Plücker's numbers for two curves does not insure that both curves belong to the same continuous system. The two C_6 with six cusps, one set on a conic, the other not, furnish an example.

The theorem of residuation of Brill and Noether is established in a new way by Gambier [45] and applied to mapping quartic surfaces with one or two double lines upon a plane. Some theorems concerning excess are established; *see also.*[46]

Fano [39] considers algebraic curves containing series that are self residual as to the canonical series, and illustrates with C of $p=5$ containing a self residual g_4^1; partial generalization to g_{p-1}^r. Some generalizations of conics by methods of differential geometry applied to trajectories are given by Jonescu.[73]

4. Curves invariant under Cremona transformations. A purely arithmetic derivation of consistent Plücker numbers is given by Meyer.[92] D'Ocagne [29] proposes a generalization of polar curves by replacing a conic by a pair of curves largely metric. A particular case is studied still further by Harmegnies.[62] Kapferer [75] submits a proof that only linear (1, 1) correspondences can exist between two non-singular curves of order >3. An alternate proof of the same theorem is given by Wirtinger [160] by means of Zeuthen's theorem. This theorem was proved by Küpper in 1892 and a much broader one which includes it by Snyder [138.1] A recent alternate proof for non-singular plane curves was given by Segre,[131] with an extension to surfaces and varieties by Severi. The number of trisecants and quadrisecants of a curve in S_3 is found by Welchman [157] by considering the curve replaced by a system of lines.

5. Trisecant surfaces of space curves. The order of the surface of trisecants is found to be

$$2\binom{n-1}{3}-(n-2)p-1/3\binom{r}{2}(8n-r-4),$$

and the number of quadrisecants is

$$\frac{1}{2}(n-3)\binom{n-2}{3}-\binom{n-3}{2}p+\binom{p}{2}$$
$$-\binom{r}{2}\left[\frac{1}{6}(n-3)(3n-2r-8)-p\right].$$

If the curve has actual multiple points these formulas must be modified. If C has h apparent double points and v_i points of multiplicity i, there are

$$\frac{1}{24}\left[12h(h-4n+11)-n(n-2)(n-3)(n-13)\right]+\sum_{i=3}^{i=m}\frac{1}{24}$$
$$v_i i(i-1)(i-2)(4n-3i-15)$$

four fold secants not through any multiple point (Schaake [127]) .

Wong [163] obtained enumerative properties of C_n in S_4 by replacing C_n by n lines with $n+p-1$ intersections and employing known formulas for transversals of lines of this system. Of the results obtained, those previously known are confirmed.

The number of tritangent planes of C_n in S_r is

$$2^r\sum_{i=0}^{q}\binom{n-q-i}{q-i}\binom{p}{i}.$$

The number of $(r+1)$ secant S_{r-1} of C_n in S_{2r} is

$$\sum_{i=1}^{q}(-1)^i\binom{n-r-2i}{r+1-2i}\binom{p}{i}.$$

Baker [9] shows that if C_n, genus p, with k cusps, lies on a quadric of S_r, and its tangents, osculating planes, . . . , osculating S_{n-1} all lie on the quadric, then $2[n+2h(p-1)]-2k$ is the number of osculating S_n to C_n on the quadric. The rational C_6 of S_3 having six points of inflexion are of two distinct types, according as the curve does or does not belong to a linear complex (Gherardelli [49, 50]). Both of the curves are self-dual.

6. Plane sextics with six cusps. Similarly, the plane curves of order 6 with six cusps belong to distinct families, according to whether the cusps lie on a conic or not. This was first mentioned by Del Pezzo without proof; cf. Segre,[129] Godeaux [54] and Villa.[153] Cusps may be at the vertices of a complete quadrilateral.

Another C_6, $p=3$ is obtained by Emch [86] by means of the symmetric (n, n) correspondence. It is the locus of the vertex of the cones in a net of quadrics and is inscribed in a complete quadrilateral.

Schaake [125, 126] considers an extension of the theorem of Poncelet.

7. Morley configurations. The configuration of Morley-Peterson was obtained by elementary methods by Mussel [101]; various forms of the configuration are discussed by Labrousse.[76] A variation of the theorem of Miquel is given by Pacquement.[106]

A further contribution of the inversion geometry of the plane bicircular C_4 is made by Ramamurti,[115] by means of four mutually orthogonal circles consisting of the axes, the unit circles centers at the origin and the circle with same center orthogonal to it. The C_4 invariant under a non cyclic G_4 is then

$$(x^2+y^2)^2+ax^2+by^2+1=0.$$

Richmond [117] gives an alternate proof, by means of symmetric functions, of the Morley theorem concerning circles and points. Lob [78.1] proved the same theorem by means of projection.

8. Special correspondences. Longhi [81] determines the number of triads of elements conjugate two by two in a symmetric non singular correspondence of grade a, valence γ and a ∞^1 algebraic entity of genus p. The number is $2\binom{a}{3}+2\binom{\gamma}{3}p-\gamma(a-\gamma)p$.

It was shown by Gherardelli [51] that every symmetric $(n-1, n-1)$ correspondence of valence 1, having a cycle of n distinct points, is cyclic and can be generated by a $g^1{}_n$.

Morley and Patterson [99] determined the invariants of biquadratic curves, and their possible components, by means of inversion. The C_4 is written as a $(2, 2)$ correspondence between a complex variable and its conjugate.

For the application to the theory of binary forms, compare Moore.[98] The condition for composition was determined by Segre.[130] *See also* McCoy.[81]

9. Hessian of a plane curve. In a series of papers Villa [150, 151] shows that the Hessian may have multiple points, even if the given curve does not. The necessary and sufficient conditions that this may happen are given. Properties analogous to those of the Hessian are generalized to apply to the rth polars by Takami.[137]

10. Incidence theorems. The theorem of Segre states that the lines of S_4 which meet four independent planes also meet a fifth. This was extended by James.[68] An $|S_2|$ meeting a C_4 of S_4 in three points and meeting a given line also meets a second C'_4. Also if $[C_4, C'_4]=6$, $|S_2|$ meets a third. The configuration is symmetric in the three curves.

Another extension is: given in S_4 two conics and two lines meeting both, the $|S_2|$ meeting all will also meet another C_2. This system is symmetric: three such congruences $|S_2|$ meet $3c_2$ and $2c_1$.[138] Various generalizations of the theorem: if $[S_2, C_4]=3$, $[S_2, C'_4]=1$, then a third C''_4 exists such that $[S_2, C''_4]=1$. Proof similar to that given by Segre for lines. That the three quartics have symmetric positions as to transversal planes was proved by another method by Telling.[137]

This incidence theorem can be generalized in various ways. The theorem is: in S_4 given two C_4, C'_4 meeting in six points; the $|S_2|$ meeting C_4 in three points, C'_4 in one, also meet a third C''_4 through the six points. The generalization made by Babbage[7] is: In S_{2n}, given C_{2n}, C'_{2n} $[C_{2n}, C'_{2n}]=2n+2$; the $|S_n|$ meeting C_{2n} in $n+1$ points and C'_{2n} in one point meet a third C''_{2n} through the same common points. A different extension of Segre's original incidence theorem is made by Room.[121] No use is made of transformations.

It was shown by Hodge[64] that there is only a finite number of birationally independent systems of plane curves of genus π with ordinary base points. On a ruled surface for which $-p_a=p>0$, any system of curves of genus π belongs to one of a finite number of simply infinite families of linear systems of curves of genus π.

Telling[139] generalizes the incidence theorem of three related quartic curves of S_4. Given a C_n of S_n; its points, tangents, osculating planes, etc., form a system; the number of points in an S_{n-1} (order), the number of tangents meeting an S_{n-2} (first rank). . . . For $n=4$, these numbers are (4, 6, 6, 4). Project from any point of S_4 upon S_3. The result is (4, 6, 6). Dually, cut system by general S_3. The result is (6, 6, 4). The first is C_4 of S_3, the second (dual) is its developed surface. C_4 lies on a quadric surface; the planes of the developable all touch a second quadric. Generalized to C_n in S_n.

11. Various theorems. Schubert's formula, $M_{n,\ r}=(r+1)(n+rp-r)$ and Castelnuovo's criterion are extended to series having variable multiple points by Maroni.[89]

Piazolla-Beloch[109] proved that every curve of order n in S_3, having the maximum index $(n-2)$ and the maximum number of circuits, has the circulation equal to the index.

Cubic and biquadratic constructions are carried out by means of two conics, first in terms of their common self-polar triangle, then in particular for circles and equilateral hyperbolas, from which the general case can be obtained by projection (Sobotka[135]). The same author[136] discusses an interesting configuration determined by a space cubic curve and four of its bisecants.

An I_3 on C_5 of S_3, $p=2$, determined by the bisecants which meet a given bisecant p generate a ruled surface R_6 and cut on C_5 an I_3 of the first class, with 8 coincidences. R_6 has C_5 and p each triply. Each p

determines an I_3 (Mikan[93]). The curve can be constructed by knowing 11 points, which must lie on a quadric surface.

A particular metric C_4 is discussed by Goormaghtigh.[56]

Longo[83] derives properties of multisecant conics of space curves by means of composite curves.

Application of Noether's fundamental theorem to the plane C_5 with three double points A, B, C and ten simple points shows that they will have three remaining points in common, provided they do not all lie on a conic through A, B, C.

Similarly given $C_6: 8P_i^2$; there are $\infty^4 C_9$ having $8P_i^3$ and through B, the ninth base point of $|C_3|: 8P_i$; these curves also pass through an arbitrary point on C_6 (Thalberg[141]).

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CHAPTER II

THE MAPPING OF SYSTEMS OF CURVES

LEAMAN A. DYE

1. Systems of lines. The mapping of systems of curves was begun by Klein[8] who mapped the lines of S_3 on the points of a quadric primal $V_4^2 \equiv p_{23}p_{14}+p_{31}p_{24}+p_{12}p_{34}=0$ in the S_5 of the six p_{ik}. A purely geometrical method of establishing this correspondence was given by Turnbull[45] and supplemented by Wren.[78] The lines of S_3 may be mapped on S_4 by projecting the V_4^2 of S_5 from a point on it into S_4. Semple[38] represents the V_4^2 on S_4 by taking for the p_{ik}, quadric primals V_3^2 through a rational normal quartic curve C_4 in S_4. The points of one of the V_3^2 correspond to the points of a prime section of the V_4^2. By considering the special cases where C_4 breaks up into a cubic and a line, or three lines and a common transversal, Semple obtains a simple representation on S_4 of congruences of lines in S_3 of the second and third orders.

Schaake[34] uses the representation of lines of S_3 upon a V_4^2 in S_5 to determine the number of bilinear congruences of lines. He[32] also uses this representation to discuss and map line complexes and congruences. Todd[42] maps the lines of S_n upon a manifold in S_N, where $N=n(n+1)/2-1$. The mapping is accomplished by the use of Plücker line coordinates; by means of the mapping the properties of doubly infinite line systems are studied.

De Vries[74] represents any line of S_3 by the focus F and the vertex V of a parabola in a fixed plane π. A line l meets π in V, and a line parallel to l through a fixed point O meets π in F; thus a (1, 1) correspondence between the lines of S_3 and the parabolas of a fixed plane may be established. A variant of this mapping is also given in the same paper. Let d, F be the directrix and focus of a parabola in a fixed plane π. Let H be a quadric surface and O a point not in π. The polar plane of F with respect to H meets the plane Od in a line l, image of the parabola determined by F and d. Conversely the polar of a line l meets π in F, and d is determined by the intersection of π and the plane Ol. The lines of a linear complex are mapped by Fischer[5] upon a conic of a fixed plane in the following manner. Let a line l of the complex meet two fixed planes π_1, π_2 in the points P_1, P_2, which are projected into the points P'_1, P'_2 in a third fixed plane π', thus mapping the line l on π'. Fix P'_1 and hence P_1; the lines of the complex through P_1 meet π_2 in points P_2 on a line, therefore P'_2 moves on a line l'_2. As P'_1 moves on a line l'_1, the line l'_2 passes through a point Q'; if Q' lies on l'_1, then l'_1 envelopes a conic which maps the complex.

Staehlin [39] establishes a correspondence between the tangent lines of a quadric cone and the points of S_3 by a suitable choice of the parameters of the tangents.

The bisecants of a rational twisted curve C_n are mapped by de Vries [50] on the points of a plane by setting up a (1, 1) correspondence between the points of the C_n and the points of a conic. The image of a bisecant of C_n is the point of intersection of the tangents to the conic at the points corresponding to the intersections of the C_n and the bisecant. de Vries [56] represents the congruence of common secants of two rational space curves on the points of a plane by the use of a projectivity between the points of the curves and the lines of two pencils of lines in a fixed plane. The map of a common secant of the two curves is the point of intersection of the two lines, one from each pencil, which correspond to the points in which the secant line meets the two curves.

A complex of lines in S_5 which meet five linear three-spaces is discussed by van Kol [24] and mapped on one of the three-spaces S_3 by relating the line to the point in which it pierces S_3. Given a point of S_3, there is just one line through it which meets the other four three-spaces. Aprile [1] discusses the systems of lines of dimension ∞^{r-1} in S_r, such that only one line of the system passes through a general point of S_r. The lines may be mapped on the points of S_r.

2. Systems of conics. The conics of S_3 are mapped on the points of S_{19} by Todd.[44] A line p_{ij} meets a plane $\Sigma a_i x_i = 0$ in the point $x_i = \Sigma a_j p_{ij}$. If the point lies on the conic $\Sigma a_i x_i = 0$, $\Sigma b_{ij} x_i x_j = 0$, then the line p_{ij} belongs to the quadratic complex $\Sigma d_{ij,\,kl} p_{ij} p_{kl} = 0$, where $d_{ij,\,kl} \equiv b_{ik} a_j a_l + b_{jl} a_i a_k - b_{il} a_j a_k - b_{jk} a_i a_l$. The 21 coefficients $d_{ij,\,kl}$ are connected by the relation $d_{12,34} + d_{31,24} + d_{23,14} = 0$, and, subject to this condition, may be taken as the coordinates of the conic in S_3 or as the coordinates of a point in S_{19}. The locus of points representing complexes of lines meeting a conic is a V_8^{92}. The equations of this manifold may be taken to be the 21 linearly independent quadratic relations among the $d_{ij,\,kl}$ which define 21 quadric primals through the V_8^{92}, together with some cubic identities of the same sort. A linear complex of conics is defined as a set of ∞^7 conics containing one member in a general pencil of conics and is given analytically by a linear relation $\Sigma a_{ij,\,kl} d_{ij,\,kl} = 0$.

A correspondence between the ∞^4 conics through a fixed point P in a plane π and the primes of S_4 is established by Schaake.[36] To the conics through P and a point Q correspond the primes through a point Q' in S_4. As Q covers the plane π, Q' describes a ruled cubic surface F_3. The tangent planes at two points Q' of F_3 meet in a point R which corresponds to the two points Q in π, which are images of the two points Q'. Conversely through a point R of S_4 there are two planes which are tangent to F_3 at two points Q' which correspond to two points Q of π. Thus the unordered pairs of points in a plane are mapped upon the points of S_4.

Schaake[29] maps the complex of conics meeting five lines l_i on the points of S_3. To a conic corresponds the point which is the pole of the plane of the conic with respect to a fixed quadric H. To a point of S_3 corresponds the conic in the polar plane of the point with respect to the quadric H which passes through the points of intersection of the lines l_i with the plane. de Vries[52] studies a similar complex of conics in which two of the five lines are replaced by a fixed conic. Sweerts[41] discusses the complex of conics touching 5 fixed planes.

The congruence of conics through a fixed point and meeting a rational space quartic curve in four points can be represented on the points of a fixed plane (de Vries[66]). In the plane of each conic of the congruence, the chord which meets two fixed lines maps the conic by its intersection with a fixed plane. The congruence may also be mapped by establishing a (1, 1) correspondence between the planes of the conics and the points of a fixed plane. The congruence of conics through a fixed point, with a fixed secant, and meeting a twisted cubic in three points is mapped on the triads of points in a fixed plane by the intersections with the plane of the common bisecants of the cubic and the conics (de Vries[70]).

The conics through a fixed point which meet two fixed conics each in two points form a congruence which de Vries[72] maps by the quadruples of points in a fixed plane. Each set of four points in the plane determines four common secants of the two fixed conics and hence a conic of the system. If the two fixed conics are replaced by four lines, de Vries[71] maps the conics by the intersections with a fixed plane of the chords of the conics which are also transversals of a selected pair of the fixed lines. The same method of mapping is used by de Vries[77] for a congruence of conics determined by a fixed point, two fixed lines as secants, and a fixed conic meeting each conic of the system in two points. In another paper de Vries[47] deals with the case where the conics are restricted to orthogonal hyperbolas meeting four lines.

de Vries[46] sets up a trilinear correspondence between the ranges of points (A), (B), (C) lying on three lines a, b, c. Through each triad of points A, B, C passes a conic meeting a fixed conic twice. The conics form a congruence which may be mapped on a plane in any one of several ways. If a (1, 1) correspondence is established between the conics of a bilinear congruence and the lines of a congruence of lines meeting two fixed lines, then the congruence of conics can be mapped on a fixed plane by the piercing points of the lines of the line congruence (de Vries [55]).

van Kol [23] uses a representation of a congruence of conics in a linear S_4, on the points and lines of a plane in studying systems of such congruences. Complexes of conics in S_4 are mapped on the points of S_3 and formulas of characteristics are derived by the methods of enumerative geometry by James.[7] The scheme is generalized by Miglio.[27] All the V^r_{r-1} of S_r passing through r given S_{r-2}, represent the primal sections of $V^{r!}_r$ of S_n $(n=2^r-1)$ having r pencils of $V^{(r-1)!}_{r-1}$. The rV^r_{r-1}, passing through rS_{r-2} have in common, apart from these, a $V^{r!}_0$, that is $r!$ points. They are the images of the primal sections of $V^{r!}_r$, of S_n.

3. Systems of cubics. The cubics of a plane are mapped upon the points of manifolds in S_9 by Yerushalmy,[79] the order and dimensionality of a manifold depending upon the nature of the system of cubics; for example, the cuspidal cubics are mapped upon the points of a $V_7{}^{24}$ in S_9.

There are ∞^4 space cubics C_3 which pass through two fixed points and have two fixed lines l_i as bisecants. This system of cubics is mapped upon the points of S_4 by van Kol.[10] Take two quadric primals H_i in S_4 each having a double line and establish a projective correspondence between the planes of H_i and the points of the lines l_i. The map of a C_3 is the point of intersection of the four tangent primes to the primals H_i at the planes which correspond to the points of intersection of C_3 with l_i. van Kol [9] establishes a (1, 4) correspondence between the curves of a complex of space cubics and the points of S_3. The complex of cubics is made up of those through two fixed points D_1, D_2 and having a line a_1 as a secant and two lines a_2, a_3 as bisecants. A (1, 1) correspondence is set up between the points of the three lines a_i and the planes through three other fixed lines a'_i. Let a cubic of the complex meet a_1 in A_1, a_2 in A_2, A'_2 and a_3, in A_3, A'_3 and call the planes corresponding to these points α_1, α_2, α_2', α_3 and α_3'. To this cubic is associated the quadruple determined by the intersections of $\alpha_1\alpha_2\alpha_3$, $\alpha_1\alpha_2\alpha_3'$ $\alpha_1\alpha_2'\alpha_3$, and $\alpha_1\alpha_2'\alpha_3'$. Conversely, take a point P of S_3, then the planes Pa'_i determine the points A_i on the lines a_i. Let H be the quadric through the points

D_1, D_2, A_1 and the lines a_2, a_3. The image of P in the (1, 4) correspondence is that cubic which lies on H and has a_2, a_3 as bisecants and passes through D_1, D_2, A_1, A_2 and A_3.

The complex of twisted cubics through two fixed points, with three fixed lines as secants and having another fixed line as a bisecant, can be represented on the points of S_3 (van Kol[18]). Set up a (1, 1) correspondence between the points of the three secants and the planes of three pencils of planes. The representation on S_3 of a curve of the complex is the point of intersection of the three planes, one from each pencil, which correspond to the three points in which the cubic meets the three fixed secant lines.

The ∞^2 space cubics through five points is called the congruence of Reye. Each line through a basis point of the congruence is the bisecant of one and only one curve of the system. This property may be used to map the congruence on the points of a fixed plane (de Vries[54, 69]). The congruence may also be mapped by the intersections with a fixed plane of the tangents to the cubics at one of the basis points (de Vries[62]). In the same paper de Vries maps the congruence by the residual intersections of the curves with a fixed plane through two of the basis points. This congruence is also discussed by de Vries.[49, 59]

The congruence of cubics through four points and having a fixed line l as a bisecant can be represented on the points of a fixed plane π through l. Schaake[30] establishes a (1, 1) correspondence between the points of l and the points of a fixed conic in π. The map of a cubic of the congruence is the point of intersection of the tangents to the conic at the points which correspond to the points of intersection of the cubic and l. de Vries[75] maps this congruence by means of the intersections of the tangents to the cubics at one of the fixed points with a fixed plane. de Vries[63, 48] maps the cubics of a doubly infinite system having a common bisecant l on the points of a plane through l. In another paper he[64] represents the cubics through four points and meeting a fixed conic twice by the poles of the common chords of the cubics and the conic.

Schaake[31] maps the ∞^2 cubics through four fixed points and with two fixed lines l_i as secants on the points of a plane π. Take two points P_i in π and establish a projectivity between the points of l_i and the lines on P_i. The congruence is mapped by the intersections of pairs of lines from the two pencils which correspond to pairs of points on the secant lines and also on the cubics. This same method of mapping is used by de Vries[51] in representing the system of cubics through three fixed points, with two fixed lines as secants and with a third line as a bisecant. The congruence discussed by Schaake[31] is also mapped by de Vries[76] on the points of a plane by the lines joining the intersections of the cubics with the fixed secant lines.

If two pencils of quadric surfaces have a basis line in common, then the residual intersections of pairs of quadrics, one from each pencil, make up a congruence of twisted cubics. This congruence is sometimes called the congruence of Veneroni and is bilinear. de Vries[60] maps it on a fixed plane by the intersections of the bisecants of the cubics passing through a fixed point. Hoestra[6] also considers this congruence along with those of Reye and of Stuyvaert (the cubics through three points and having three fixed lines as bisecants).

The congruence of cubics through a fixed point and with four fixed lines as bisecants is mapped on the points of a plane by van Kol.[20] He establishes a projectivity between the points of one of the fixed chords and the tangent lines to some fixed conic. The intersections of pairs of tangents to the conic is used to map the congruence. de Vries[61] and van Kol[21] use a similar method to map the system of cubics having five fixed lines as bisecants. The system of ∞^2 cubics determined by one point and five lines, two of which are secants and three being bisecants, is discussed and mapped by de Vries[57] on the points of a plane, by establishing a projectivity between the points of the two secants and the lines of two pencils in the mapping plane.

4. Systems of quartics. There are ∞^6 rational space quartics through five points P_i of S_3. Take a point Q in S_4, and on the lines QP_i take five points O_i as the vertices of the simplex of reference. By projection, a quartic through the five points P_i is associated with a quartic through the five points O_i, which is transformed into a line in S_4 by the transformation $x_i x'_i = 1$. Conversely a line of S_4 goes into a quartic through the five O_i which corresponds to a quartic through the five P_i. In this way Schaake[35] maps the system on the lines of S_4. van Kol[11] maps the ∞^6 rational quartics through five points of S_4 by the same device and then goes on to consider simpler systems of quartics. The congruence through six points and meeting a fixed plane is mapped on a plane through three of the points. The congruence through five points and having a fixed line as a bisecant is mapped by the use of a projectivity between the points of the bisecant and the points of a fixed conic. The intersections of pairs of tangents map the congruence on the points of the plane of the conic. The congruence of quartics through five points and having a pair of fixed lines as secants is mapped on the points of a plane by the aid of a projectivity between the points of the secants and the lines of two pencils in the mapping plane.

The congruence of rational quartics through seven points P_i is mapped on the points of a plane by Schaake.[33] Any line l through P_7 determines, with the remaining $6P_i$, a cubic cone on which l is a double line and the six lines P_7P_i are simple. The line l and the six points P_i also determine a quadric which meets the cubic cone in a residual quartic of the congruence obtained by considering all lines l through P_7. The mapping is accomplished by the use of the intersections of l with a fixed plane.

van Kol[19] discusses a congruence of rational space quartics through six points P_i and having a fixed line through P_1 as a trisecant. He also considers the congruence of rational quartics through four points and having one fixed line as a secant, another as a bisecant and a third as a trisecant. These congruences may be mapped on the points of a fixed plane through the trisecant line. The same mapping may be used for the congruence of rational quartics through two points and having two fixed lines as bisecants and two others as trisecants (de Vries[67]).

The ∞^4 elliptic quartics through six points are determined by the intersections of pairs of quadrics, one from each of two nets of quadrics having six points in common. The quartics are mapped upon the points of S_4 by van Kol,[13] who sets up a (1, 1) correspondence between the quadrics of the two nets in S_3 and the planes of two nets through two lines in S_4. A quartic of the system is represented by the point of intersection of the two planes which correspond to the two quadrics which determine the quartic curve.

A pencil of quadrics $H_1: 5P_i+l$ and a web of quadrics $H_2: 5P_i+Q$ determine a system of ∞^4 elliptic quartics through the five points P_i and having the line l as a bisecant. van Kol[25] establishes a (1, 1) correspondence between the quadrics of the pencil H_1 and the $|S_3|$ through a plane π of S_4 and also sets up a correspondence between the web of quadrics H_2 and the ∞^3 lines through some point O of S_4. The points of intersection of the lines through O and the $|S_3|$ through π are the maps of the quartics determined by the corresponding quadrics.

van Kol[17] studies the system of ∞^4 elliptic quartics through four points P_i and having two lines l_i as secants and a third line l_3 as a bisecant. He establishes a (1, 1) correspondence between the points of l_1, l_2 and the primes of two pencils in S_4. The points of l_3 are made projective with the tangent primes to a quadric primal V_3^2 having a double line. To a quartic of the system corresponds the point of intersection of the four primes which correspond to the points common to the quartic and the three lines l_i. Another system of ∞^4 elliptic quartics is considered by van Kol.[15]

The complex of elliptic quartics through five points and having three fixed lines as secants is mapped on the points of S_3 by means of a (1, 1) correspondence between the points of the secants and the planes of three pencils of planes (van Kol [22]). The complex of elliptic quartics through five points, with a line l_1 as a secant, and a line l_2 as a bisecant, is mapped upon the points of S_3 by van Kol.[12] He uses a (1, 1) correspondence between the points of l_1 and the tangent planes to a fixed quadric cone, and another such correspondence between the points of l_2 and the planes of a pencil through a fixed line. In another paper van Kol [16] discusses the complex of quartic curves in S_4 which have five fixed points as basis points and meet a fixed plane in a fixed line.

Two pencils of quadric surfaces have the elliptic quartic curves C_4 and C'_4 as basis curves, respectively. The intersections of two quadrics, one from each pencil, is an elliptic quartic of a congruence which is mapped by de Vries [58] on the points of a plane. Let P be a point of C_4, and P' a point of C'_4. The tangent planes to the quadrics at P, P' constitute two pencils of planes (p), (p'), which are made projective with two pencils of lines in a fixed plane. The map of a quartic of the congruence is the point of intersection of the two lines of the two pencils which correspond to the pair of planes, which are tangent to the quadrics determining the quartic curve. de Vries [73] maps the bilinear congruence of elliptic quartics determined by two pencils of quadrics, by the pairs of intersections with a fixed plane of the pairs of bisecants of each quartic which pass through a fixed point.

Another congruence of elliptic quartics through five fixed points and with two fixed lines as bisecants is given by the intersections of quadrics chosen from two pencils each having the five fixed points and one of the fixed lines as basis elements. This congruence is discussed by de Vries [65]; it may be mapped by the preceding method if the fixed point is taken on one of the fixed bisecants. van Kol [26] studies a congruence of elliptic quartics through six points and meeting a fixed conic twice. This congruence can be mapped on the plane of the conic.

5. Miscellaneous. de Vries [53] discusses a congruence of plane monoids made up of those plane curves of order n having an $(n-1)$-fold point at a fixed point P, and having $2n$ lines of S_3 as secants. The congruence can be mapped by its planes.

Two points O, O' and $(2n-1)$ points P_i determine two pencils of cones K, K' of order n through the lines OP_i and $O'P_i$, respectively, and each having the line OO' as an $(n-1)$-fold line. The two pencils determine a congruence of C_{2n-1} of genus zero, with O, O' as $(n-1)$-fold points and with the $(2n-1)$ P_i as simple basis points. de Vries[65] maps the congruence by the residual intersections with a fixed plane through the line OO'.

van Kol[14] maps a complex of planes of S_4 upon the points of S_3. Rao[28] obtains a representation of the planes of S_5 upon a manifold V_9 in S_{19}. In Rao's paper three points A, B, C in S_5 determine the plane whose coordinates p_{ijk} are the 20 third order determinants of the matrix $(a_ib_ic_i)$. The p_{ijk} are interpreted as point coordinates in S_{19}, and the 30 linearly independent quadratic relations among them may be taken as the equations of the V_9 on which the planes are mapped.

The S_k's of S_n may be considered as points of a Grassmanian variety $V_{(n-k)(k+1)}$ in S_N, where $N=\binom{n+1}{k+1}-1$. Brown[2] shows that those S_k's of S_n which are chordal ($k+1$ secant) to a rational normal C_n in S_n are represented by the points of a Veronese variety V_{k+1} lying in a Grassmanian variety, where the V_{k+1} is the map on S_N of a S_{k+1} by means of its primals of order $n-1$.

Edge[3] maps the quadrics of a net on the points of a plane, thus establishing a (1, 1) correspondence between a $C_6(p=3)$ and a quartic curve in the plane. He[4] generalizes these results by mapping a net of quadrics in S_n on the points of a plane π. He then maps the base curve θ of the net on the points of a curve in the plane π, and determines its order and genus.

Sorrentino-Giordano[40] represents the points of S_4 by ordered pairs of points in a plane π by means of two lines l_i. If P is a point of S_4, then the planes Pl_i meet π in two points P_i; conversely, given two points P_i in π, the planes P_1l_1 and P_2l_2 meet in a point P.

Todd[48] discusses the configuration defined by six lines in S_3. There are ∞^4 quartic surfaces passing through six arbitrary lines in S_3. Since the points of S_3 may be mapped on a $V_3{}^4$ of S_4, the points of any quartic surface of the system corresponds to a prime section of the $V_3{}^4$. The $V_3{}^4$ has 36 nodes, is determinantal and is capable of projective generation in 15 ways. To the interchange of conjugate systems of curves and surface on $V_3{}^4$ corresponds a Cremona transformation in S_3 of order 19.

Semple[37] studies a linear system of cubic surfaces $\Phi\equiv\Sigma_0{}^r\lambda_iF_i=0$, of freedom $r\geqq 4$. Let the coordinates of a point P in S_r be proportional to F_i; then to a point Q of S_3 corresponds a point P of S_r, and as Q describes the S_3, P describes a $V_3{}^n$, where n is the grade of Φ. To the points of a surface of Φ corresponds a prime section of $V_3{}^n$. Cremona transformations are obtained by projection of $V_3{}^n$ upon another S_3.

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CHAPTER III

SYSTEMS OF LINES IN S_n; IRREGULAR SURFACES

VIRGIL SNYDER

1. Complexes. The linear line complex in S_3 can be generated by the method of Sylvester and by that of Chasles. The former has been generalized to S_n. Weiss [82] generalizes that of Chasles, the transversals of the pair of lines forming an involution on a regulus. This is extended to S_5 and then to S_{2p+1}.

Segre [69] has continued his study of the general quadratic complex in S_4. Todd [78] finds a locus in hyperspace which represents the lines of S_4, similar to the quadric primal in S_5 for the lines of S_3. He applies it to the linear complexes.

Lines of hyperspace are determined by two points or by systems of primals passing through them. The word complex is applied to a system of ∞^3 or more of lines, the exact meaning not being always evident from the context. A linear complex is said to be of the first, second, third, etc., species, according to the dimensionality of the points through which pass ∞^2 (or more) lines.

Thus, if a complex Γ of lines of S_4 is of the third species the locus of its singular points is a surface ξ. If ξ is a plane, the lines of Γ in any S_3 through ξ is a congruence γ without singular lines. Aprile [2] considers a Cremona transformation between ξ and another plane ξ' in the same S_3. The lines joining corresponding points describe a primal of order m, on which ξ is of multiplicity $m-1$. If the Cremona transformation is linear, the locus of points which determine the projectivity is a curve h, which has $h-1$ points on ξ. Relations among various complexes, linear or of orders k_1, k_2, . . . are obtained, having in ξ a curve of singular points of orders k_i-1. The Cremona transformation has the same characteristics in each S_3 through ξ; *see* the earlier paper by Aprile.[1]

Segre [68] defines a complex Ω as an aggregate of ∞^{2n-3} lines of S_n. The order m is the number of lines of Ω in an arbitrary pencil. A pencil is called tangent if two of the m lines coincide. An $S_{n'}$ in S_n contains $\infty^{2n'-3}$ lines, which constitute the section of Ω by $S_{n'}$. A projective correspondence exists between the tangent cones along a line and the points of the line. The envelope of singular S_{n-1} and the locus of singular points are the same primal.

A 4-complex Γ is the system of ∞^4 lines in (1, 1) correspondence with the points of S_4. Sgroi [70] classifies them into 13 types. A singular point is of the i-species if through it passes ∞^i lines of Γ. A plane is an i-parasite if every line in it is i fold for Γ. Every focal plane touches the focal primal in three points. A 4-complex of type (1, 0, 1) is generated by the lines incident to a given line and a given S_3. (0, 1, 2) is generated by lines incident to two given S_3 and a given S_2, (0, 0, 4) by lines incident to four given S_3.

Todd [77] generalizes the method of generating the tetrahedral complex in S_3 to apply in hyperspace. Consider lines meeting k given S_{r-1} of S_r in points projective with a given system of k points. Proved directly for $r=2$, 3, 4, then by induction. The ∞^2 lines of S_3 meeting five fixed planes in a given range form the axes of a cubic developable containing the five planes. The lines meeting six planes of S_3 projectively generate a quadric touching them.

A complete classification of complexes of S_4 of the third species, including those of order 2 was made by Miglio.[45] Seven types are obtained, making use of the methods and results of Marletta. The same author applies a somewhat similar procedure to the study of ∞^3 complexes of plane curves of order $n>1$ in S_4. The order of the complex is the number of its curves through a point; its class is the number in a primal S_3. The easiest case is that in which the curves are arranged in ∞^2 planes. If Γ consists of curves in ∞^3 planes, the discussion is limited to complexes of order 1 or 2 and to class 1. Various methods of generating such complexes are given.

Marletta [41] proposes a method of studying $(r-1)$-complexes of lines in S_r. Given two superposed S_r, projectively related with distinct fixed points. A complex Γ is defined as the totality of lines joining corresponding points. For $r=3$, the tetrahedral complex results; for $r=4$, that studied by Aprile [Mem. Acc. Zelanti (3), 6 (1908)]. The complex Γ is rational and invariant under Ω; it is of order $r-1$, and can be mapped on the points of S_{r-1} by incidence. Lines of a cone of Γ are transformed into the points of a rational curve. These curves form a complex Λ having the fixed points of Ω for its only base points. It is always possible by means of a Cremona transformation to transform the $\infty^{2(r-1)}$ rational curves through $r+1$ fixed points of Ω into lines of S_r (Bennati [10]). Parisi [49] describes some cubic line complexes of S_4. These have a surface δ of singular points. The congruence in any S_3 has a singular curve. The surfaces of S_4 which generate complexes of order 3 are: rational ruled R_4 with two directrix conics not in same S_3, R_4 with C_3 and C_1 not in same S_3, projection of the Veronese surface. All these are generated by chords. Three such complexes are generated by lines in planes of conics obtained by projecting from a generator of a normal cubic scroll a curve C upon it. The curve is section having as trisecants a C_5 with three generators as chords, and C_4 meeting each once. Every sextic ruled surface R_6, $p=1$ of S_5 has either just two (distinct or coincident) plane cubic curve sections or an infinite number. Every elliptic R_6 with ∞^1 plane cubic curves is the locus of the line centers of three distinct nets of linear complexes (Fano[21]). The same author[22] showed that the ∞^3 variety of the base lines of an ∞^4 linear system of linear complexes of S_5 is birationally equivalent to a general cubic variety of S_4. The Grassmannian $M_8{}^{14}$ of S_{14} of the lines of S_5 is met by any general S_{14-i}, $i<6$ in $M_{8-i}{}^{14}$ on which the prime sections constitute a minimum base.

Complexes of space cubic curves which cover S_4 simply have been determined by Privitera.[51.1]

Gherardelli[25.1] proved that if a system of plane curves of dimension $r>1$ is linear, both as a point locus and as a line envelope, the system is composed of conics. There are three types:

$\infty^2|C_2|$ with a common self-polar triangle.
$\infty^3|C_2|$ with a given point and given line for pole and polar.
$\infty^5|C_2|$ of S_2.

Marletta[41.1] discusses complexes of curves in S_r and proves the following theorem: In S_r every $(r-1)$ irreducible complex of order 1 of rational normal curves $|C_r|$ such that $\infty^r S_k$ meet the curves in $k+1$ points for every value of k is generated by those rational normal curves which pass through $r+1$ given independent points and meet a given S_{r-2} in $r-1$ points.

Sapienza[66] maps an $(r-1)$-complex on the points of S_{r-1}. It is shown that the focal surface of order $2(r-1)$ coincides with the envelope of the S_{r-2} of the system. Earlier papers on complexes of lines in S_4 by Marletta are Atti Acc. Gioenia Cat. (3), 3, No. 5 (1894); *ibid.* (5), 3 (1909); 6, No. 1 (1913). Rosenblatt[59] considers varieties determined by matrices (Grassmannian). To lines on a Grassmann variety correspond pencils of linear spaces. On a Grassmann variety are two families of linear spaces. One is composed of S_{k+1} and S_k of S_{k+1} in S_r. The other is composed of S_{r-k} bundles of axis S_{k-1} of S_r. The first has $\infty^{(r-k-1)(k+2)}S_{k+1}$ and the second contains $\infty^{k(r-k+1)}S_{r-k}$.

2. Ruled surfaces and other systems. By means of the degeneration method the formula is obtained for the number of planes which satisfy a certain set of conditions in S_n. The number of planes in S_{2n} meeting $6S_{n-1}$ is $n(n+1)(n^2+n+4)/12$. This agrees with the particular interpretation of the more general formula obtained by Giambelli (Todd [75]). Weitzenböck [83] considers the transversals of four planes in S_5. Three lines meet all of them. The equations of the transversal lines are determined and some invariants concerning them derived. Welchman [86] generalizes the generation of a quadric or more generally a ruled surface in S_3 to study figures generated by $\infty^1 S_2$ in S_4. Details are given for orders 3, 4 and 5. These forms are all rational. This author [84,85] also generalizes the incidence theorem of Segre (1888), which states that the planes of S_4 which meet four lines also meet a fifth. The planes of S_4 meeting a rational normal C_4 in three points and also meeting a line meet a second C''_4 (James [32.1]). Other cases were given by Pieri. Consider systems of $\infty^2 S_2$ in S_4, two through each point. If more pass through a point it is singular. Given two C_4 meeting in six points. The congruence of planes trisecant to one and meeting the other once is examined and all possible degenerate cases given.

Aprile [3] considers line complexes Γ of order 1 in S_r defined by the transversals meeting $x_i S_i$, where i may be any number $\leqq r-2$, and $\Sigma(r-i-1)x_i = r-1$. These are replaced in part by certain rational varieties. A Cremona transformation is defined in S_{r-1} by means of this complex. Given S_{r-1}, S'_{r-1} in S_r. A point P in S_{r-1} has a single line g of Γ passing through it, and this meets S'_{r-1} in the image point P'. It is a direct generalization of the Steiner construction for a quadratic inversion between two planes π, π' in S_3 by means of two skew lines u, v.

Panello [47] applies Segre's representation of lines to S_3, in particular ∞^2 lines of a pencil of quadrics; they are mapped on the ∞^1 points of an elliptic curve C_7 in S_5 in which the pairs of incident lines generate a g^1_2; the four double points are the images of the bundles whose vertices are the vertices of the cones of the pencil.

The same author [48] also considers a pencil of quadrics expressed in terms of the common self polar tetrahedron. The line coordinates p_{ik} of each generator are obtained and the linear complex to which each belongs is determined, then these are interpreted as points of a quadric primal in S_5. The locus is expressed by the vanishing of the determinants of a matrix. The modifications necessary to apply to other pencils are outlined. A representation of S_k contained in an S_m on the points of $[(m-k)(k+1)]$ by means of Grassmann coordinates is expressed by the vanishing of certain determinants of a matrix by Room.[58]

van Slooten [79] derives further properties of inflexional tangents, conflecnodal curves on a general surface of order n in S_3, generalizations of the 27 lines on a cubic surface.

Weiss [81] gives an alternative proof of the invariant defined by four planes in [5]. For the geometry of S_k contained in S_n, *see* Morin.[46]

Algebraic surfaces containing an infinite number of conics, particularly quintic surfaces, are given by Marletta.[41.3]

There are three kinds of non-ruled surfaces of order n in S_{n-1}: (1) non-normal, obtained by projecting surfaces of order n in S_n from an external point; (2) surfaces of Veronese and of Segre projected from two points not on the surface—including the Steiner surface of S_3; (3) normal surfaces with spatial sections of genus 2. The only non-ruled surfaces of order n in S_{n+1} are those of Veronese and of Segre, or those of order n in S_n discussed by del Pezzo. An $(n-1, n)$ can be projected into a quartic surface with a double line in S_3 (del Re [52]). The double points of algebraic primals in S_k are discussed by the same author.[53] Forms of multiple points are discussed by means of polars and of the Hessian. If of the first kind on the given curve it is also of the first kind on the Hessian with the same tangent cone.

Doubly infinite systems of lines in hyperspace are studied by Todd [79] by means of their Grassmannian coordinates, interpreted as point coordinates of a variety in another space. The systems considered are those represented by non-ruled surfaces with rational or elliptic prime sections. It is shown that the line systems generate three dimensional loci which are closely related to each other; they can be derived as projections of known loci.

James [82] defines a system of characteristics in terms of which it is possible to express the orders of varieties generated by lines which satisfy given incidence and other conditions. From this system can be obtained the characteristics of the intersection of two such systems and so on.

Curved n-dimensional varieties containing n systems of straight lines are derived by Barrau.[8] Let x_1, x_2 be the homogeneous coordinates of a point on one line S_1; y_1, y_2, those of another. Then $\xi_{ik}=x_i y_k$ determine a point on an H_2 in S_3. (Identity among ξ_{ik}.) Consider three lines x, y, z; then $\xi_{ikl}\equiv x_i y_k z_l$ define a sextic three dimensional variety in S_7, etc.

3. Geometry of the sphere. The line elements of S_2 can be mapped on the minimal lines of S_3 and the points of S_3 on the minimal lines of another S_3 (Beck [9]). The points of the projective planes can be mapped by a (1, 1) correspondence on the isotropic lines of S_3. Two distinct minimal lines determine a sphere in a conformal space. Hence the lines of S_3 are mapped on the ∞^4 spheres of a conformal space.

A linear congruence of lines of S_3 is mapped on the points of a plane, then this map is interpreted in terms of congruences of spheres by means of the polar theory of the circle by Haenzel.[31] The method is novel; no new results are mentioned. By the use of this and various other methods, Matsumura[42] gives a number of further details on the geometry of circles and of spheres.

4. Surfaces and varieties; irregularity. If a surface of genera 1, with non hyper-elliptic plane sections and canonical curves of genus $p>4$ is not the complete section of a system of quadric primals through it, then the complete section is either (a) a normal three dimensional variety V_{p-2} generated by ∞^1 planes, the surface being cut by a cubic variety through $p-4$ of its planes, or (b), if $p=6$, a conical V_4 which projects a surface of Veronese from a point, the surface itself being cut on V_4 by a cubic variety through one of the quadric cones which project the conics of a surface of Veronese.

The only general type of surface having canonical curves of genus 6 for primal sections is the quadric section of $V_3{}^5$ which represent the lines common to three linear complexes of S_4. It may have a double point in two different ways, each imposing one condition (Du Val[17, 18]).

Fubini[23] showed that the only surfaces of S_3 with collinear plane sections are either cones or quadrics, certain cubics and certain quartics. A surface representing pairs of non ordered points of a curve $p>0$ is irregular. If the curve belongs to an irrational involution, so does the surface. The image of the involution is irregular. If a curve L belongs to a cyclic i_p of order p, without fixed points, and the image of i_p is L', for which $\pi'-1=p(\pi-1)$, then i_p is determined by a cyclic Cremona transformation. The image in S_r is a collineation with axes $\epsilon, \epsilon^2, \ldots \epsilon^p=1$. (Godeaux[27]). Dubreil[15] extended Noether's theorem to surfaces and to varieties. The necessary and sufficient condition that every form F vanish simply on C and at the points M satisfying the condition $F=\Sigma a_i F_i$ is that the curve C_r meets (F_i, F_k) outside of C only in first species.

Generalizations of the theorem of Noether extend to linear systems of higher dimensions of curves having a certain number of common base points. The system which serves to characterize the set of base points is called the ideal (Gambier,[24, 25] Legaut,[33, 34] Dubreil,[12-16] Macaulay,[37] Sperner[78]).

The papers of Dubreil extend the results to derive theorems concerning the base for space curves.

Babbage[5] describes a rational surface of order 8 in S_5, mapped on a plane by $|C_7|: P^3 8P^2$. It has a double line corresponding to C_3, $p=1$ through all nine base points. Four types are discussed. A fifth is added,[6] mapped by $|C_9|: 8P^3 P^2$.

Roth[65] derives a series of formulas for the regularity of a surface in S_n by means of the Riemann-Roth theorem $\rho = p_a + n - \pi + 1 - i + \delta$. The effective dimension ρ' is given by $\rho' = p_a + n - \pi + 1 - i$. If F is not mappable on a ruled surface and $\pi > n$, then $|C|$ is non-special and virtually effective. If $2\pi = n + 3$ and $2r > n - 1$, F is either regular or referable. If $|C|$ is virtually effective and $\pi > \pi_r(n)$, then F is regular. Torroja[80] shows that every algebraic biuniform correspondence between two spaces or algebraic varieties of different dimensionality has necessarily exceptional elements. It is not possible to establish such a correspondence without exception between the points of a space or variety and groups of points of another space or variety unless the sums of the dimensions in the two cases are equal.

Baker[7] considers V_3^3 of S_4 with 10 nodes as section of Perazzo's $V_4^{(3)}$ of S_5 and points out its connection with the del Pezzo surface, mapped by $|C_3| : 4P'$. Godeaux[26.1] finds 63 pairs of conics and 63 pencils of rational space quartics on Cremona's quartic surface with a tacnode and an adjacent infinitesimal double line. It can be mapped on a double plane with a non singular C_4 for curve of branch-points. The same author[26.2] also shows that the Humbert quartic is invariant under a collineation of period 7.

Further criteria for the regularity of surfaces have been determined by Roth.[65] In S_3 all surfaces of order <8, with ordinary singularities, are regular or referable to a ruled surface. In S_4, all non-singular ones of order <10 are regular or referable; with one exception, also those of order 10; in S_5, $n<12$; $n=12$ with one exception; in S_6, $n<14$; $n=14$ with one possible exception. The exception in each case is that of an elliptic or hyperelliptic surface, normal in the space considered.

The surfaces whose prime sections contain a g^1_3 have been determined by Bronowski.[11.1] The five existing types of rational surfaces were known before.[11] The present paper generalizes to higher genera. There is one type of genus $p = 3i - 1$ and two for all other genera.

5. Involutions on surfaces. Snyder[72.1] points out the rôle played by the general V_3^3 of S_4 in the study of possible irrational involutions of S_3; 104 references are given.

Sauer[67] discusses the topological problem of mapping one plane on another by means of triangles. Consider $x'_i = \phi_i(x)$, each ϕ_i being quadratic; it is multiple if $|\phi|$ have less than three fixed base points. In the system are pencils with composite conics, forming triangles; 10 cases are considered. The three lines through a point are tangent to a curve of class 3. When $p=1$, these are expressed in terms of elliptic functions.

Godeaux[28] continues his studies of cyclic involutions having no fixed points. Let I_p be a cyclic involution generated by a Cremona transformation of period $p=p_a+1$ having no fixed points on the given regular surface F. Then Φ, image of I_p, is regular with arithmetic genus π_a. $p_a+1=p(\pi_a+1)$, $p^{(1)}-1=p(n^{(1)}-1)$. The canonical system $|C|$ of F contains $p-1$ isolated curves, invariant under T. The order of I_p is odd and the bigenus of Φ is at least $(p-1)/2$. The linear genus of $F>10$. If $p_a>1$, $P_2>10$. The author continues[29] with irregular surfaces. If F' has $p_g-p_a=q'$, has no irrational pencil of curves and contains an involution I_p, then the image F has irregularity q and the varieties V, V' of Picard have the properties: V contains I_p, the image of which is abelian and belongs to V' or V contains pI_p, the images of which on V' do not meet by pairs. Godeaux[30] also considers an F_8 obtained from a Steiner surface $F(y')$ by a quadratic transformation without base points $y_i=\phi_i(x)$. It has eight triple points and three double quartic curves $p=1$ through them. The same author[30.1] considers the fixed fundamental points of an I_2 belonging to an algebraic surface, generalizing an earlier note.[26.3]

An alternate proof of the theorems of Enriques (Bologna Rend., 1908), that a surface of genera 0 and bigenus 1 represents an involution of order 2 having no fixed points and belonging to a surface of genus 1, is given by Godeaux.[30.2] Conversely, if an algebraic surface of $p_g=p_a=1$ possesses an involution of order 2 without fixed points, the image surface of the involution has genera $p_g=p_a=0$, $P_2>0$ (Godeaux).[30.3] A quartic surface $p_a=P_4=1$ with four ordinary uniplanar double points and three conical points represents an involution of order 4 on a double plane of genera 1, with branch curve consisting of three conics mutually bitangent. Seven planes touch the quartic surface along irreducible conics (Godeaux[30.4]). If an I_2 of S_3 has a finite number of fixed points, this must be 8 (Godeaux[30.5]). Godeaux[30.1] gives further details of an I_2 on an algebraic surface, with fixed points that are also fundamental points. Rational correspondences between two irregular surfaces are studied by the same author.[29] These various results are collected and elaborated in *Les surfaces algébriques non rationnelles de genre arithmétique et géométrique nuls. Exposés de Géométrie IV.* Hermann, Paris, 1934.

6. Characteristics of surfaces. The characteristics of a surface V_2^n in S_4 are all expressible in terms of four of them (Severi). For ruled surfaces various modifications must be made on account of multiply secant lines, inflexional tangents and tangents elsewhere secants (Roth[61]).

Loci which have two systems of generating spaces have been discussed by Richmond and Bath.[67] Systems of S_p and S_q in S_{p+q+1} which intersect, generate the loci in question. For all values there exist in S_{p+q+1}, $\infty^p S_p$ and $\infty^q S_q$ such that any S_p intersects every S_q.

If V_3^3 of S_4 contains no plane, and consequently has less than six double points, it contains only complete intersections (Fano). The primals of any given order cut from V_3^3 a complete linear system (Archbold[4]). Baker[7] supplies a number of formulas concerning chordal curves and trisecant curves for rational surfaces of S_4, with the plane map of some of them.

Osculating and cor-osculating spaces of primals of S_k are discussed by del Re.[55,56] The dual of an osculating S_k in S_h, $h<k$ is a cor-osculator. It is not defined at a point of a line lying on the surface or variety.

7. Generation of curves, surfaces and varieties. A family of surfaces of S_6 is obtained from pairs of points of a curve of $p=3$, each point on the surface F mapping two pairs of points of the curve C (Humbert). The projective model is a surface of order 12 in S_6, with 28 conical double points, and 63 S_5 touching it along a curve of order 6 and genus 1. In S_6 consider the V_3^4, which projects a surface of Veronese. F is cut from this cone by a cubic primal touching the cone in 28 points. It is invariant under a Cremona transformation with four fixed points (Godeaux[26]). A rational surface F of order 7 in S_5 is mapped on a plane by the $|C_4|:9P'$, the base points being also the base of a pencil of cubic curves. The spatial sections f of F are of order 7, genus 3, in S_4, hence normal (del Re[53]). The theorem that if two non-singular plane curves are in (1, 1) correspondence they are projectively equivalent is generalized by Severi[71] to apply to varieties in S_r without multiple points.

Bronowski[11] maps a rational normal surface of S_4 having two skew double lines and obtains its characteristic properties.

An alternate proof of the theorem of Welchman concerning two normal C_4 with six intersections is given by Edge,[19] who derives other properties of the configuration employed.

Further incidence theorems are given by Perazzo.[50] In S_5, the ∞^2 lines incident to three planes meet ∞^1 planes, projective along collinear nets of S_3. The ∞^1 planes dual hereto can be defined as planes incident to four lines.

Incidence is studied by Eiesland.[20] The locus of ∞^{n-2} lines incident to ns_{n-2} in S_n is a ruled V^{-}_{-} , the equation of which may be written as a determinant; it may be generated projectively by $n-1$ linear ∞^{n-2} systems of S_{n-1}. Intersection with quadrics give a double S_{n-2}

on V_{n-1}^{n-1}. If n=5, 10 double lines appear at once, intersection of five S_3. These lines do not intersect. There are 20 other double lines, and five double space C_3. Only V_4^4 has triple points.

Roth[62] derives criteria for surfaces analogous to those of Enriques-Severi for curves, including the condition that a complete intersection becomes composite. The method is that of envelopes, analogues to that of Chisini.

Steed[74] generalizes the analogue of 27 lines on a cubic surface to configurations in hyperspace. There is an independent proof of Schubert's theorem that F_3 of S_4 has 2875 lines.

On a primal of order $2n-3$ of S_n exists a finite number of lines. The methods of enumerative geometry are employed.

Roth[60] discusses the Jacobian of a system of quadratic forms in S_4, incidentally treating the Cremona transformation defined by four general quadric polarities, with special interpretation of the cases in which the system includes one, two, three or four composite quadrics.

The formulas for simultaneous incidence conditions are expressed as a sum of simple conditions and applied to lines and to planes by Todd,[76] who contrasts this method with the earlier proofs involving degenerate forms (Schubert, Palatini, Pieri, Severi).

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CHAPTER IV

CREMONA TRANSFORMATIONS

VIRGIL SNYDER

1. Plane quadratic inversions. Patterson[170] examines the writings of Quetelet, Dandelin and others and concludes that the original discovery of the principle of circular and spherical inversion is due to Steiner, that it was known before 1826 but not published.

Fladt[80] considers the type to which a plane quadratic Cremona transformation belongs, by means of the rank of the determinant $|A_{11}B_{22}C_{23}|$, wherein $\rho x'_1=\Sigma A_{ik}x_ix_k$, etc. When the rank is zero, $x'_i=1/x_i$ results.

Berdiales[14] makes a general study of inversion. Contact transformations that are also birational can be expressed in terms of linear elements x, y, p. Let $x'=x'(x, y, p)$. In S_3 they are inherent in a linear complex. An example is given by the harmonic division of the bisecants of a space cubic curve. Planes go into cubic surfaces on which the given curve is asymptotic. Osculating rays go into osculating rays (Fano[76]).

Given a triangle, its inscribed and three escribed circles. Relation of the centers to the vertices is expressed by the vanishing of a certain determinant of order 4 (Herbert[113]). A continuation from[112] determines an inversion from this figure.

Dieudonné[58] obtains the generation of the plane quadratic correlation by means of a pencil of conics.

From the formula connecting a distance PQ and its inverse $P'Q'$ under circular inversion, a number of invariant relations is obtained.

Hadamard[110] gives a detailed account of recent progress in the geometry of inversion in the plane.

Excellent summaries of the field which include practically everything up to the time they were published are given by Emch[71] and by Berzolari.[15] Mehmke[150] gives further properties of transformation by reciprocal radii. Further properties of general inversion are given by Peters[172] and by Dean.[54] A generalization of ordinary inversion is proposed by Shaub.[200] For the relations between inversion and mechanisms for constructing circles and circular curves, *see* Lojciansky,[139] Rademacher and Toeplitz,[179] Zinder,[239] Delaunay,[56] Holst,[118] Hilbert and Cohn Vossen,[114] Julia,[139] Caratheodory,[35] Kowalewsky,[135, 136] Ginzel,[90] Fubini and Cech,[85] Bompiani,[21] Lane,[138] Weatherburn,[229] Delens,[57] Nakajima [167] and Muhlbach.[166]

Applications of quadratic transformations to the resolution of singularities of surfaces have been made by Sander,[186] Brauner,[23] Dumas [60-64] Hodge,[116] Dohogne,[59] and Paul [171]; *see* in particular Hudson,[121] p. 353-381.

For applications to linear systems of curves, the texts of Enriques and Chisini,[75] p. 192-199 and of Coolidge,[49] p. 401-409 should be consulted; also the following memoirs: Hodge,[115] Segre [190, 191] and Todd.[220] Zelenka [238] constructs the conic determined by five pairs of conjugate points by means of plane quadratic transformations.

Particular quadratic transformations in S_3 have been considered by Gallucci,[86] who gives a particular metric interpretation; by Godeaux,[95] giving more detail to the case of the base conic consisting of two intersecting lines and by Hudson and Wren.[123] The last corrects a statement by Aschieri, repeated by Doehlemann, that the general (2, 2) Cremona transformation in S_3 can not have an invariant pair of homologous points. It is shown that two such pairs exist.

Other cases are given by Godeaux,[97] Strazzeri [214] and Palozzi.[169]

General theorems concerning the Jacobian of a web of surfaces, particularly of a homaloidal web have been given by Villa,[225] who extends them to hyperspace.

2. Types. Given the two fundamental equations of condition for a plane Cremona transformation, the most important question is whether they represent a geometric transformation or are simply arithmetic conditions. Barber [11] employs the method of groups, as developed by Coble. If the number of F points of the Cremona transformation is $\leqq 8$, the group is finite. If this number ≥ 9, it is infinite. Any two consecutive involution conditions generate the group.

Montesano [162] gives the details of a complete series of composition of a plane Cremona transformation in terms of its quadratic components, in the fewest possible number of steps. Further details are given in [162] for the corresponding reduction in terms of Jonquières components.

The problem of types of Cremona transformations with points of only one multiplicity (symmetric forms) has been completely solved, and the arrangement of those with two sets only into definite types has been accomplished. The triadic types have been discussed by Montesano in a number of earlier essays and recently by Farnum.[78] Those having a group of simple base points in each plane are completely determined, and a considerable number of others added. The problem of reduction is considered from another point of view by Torrance,[221] who supplements the results obtained by Montesano.

de Martino [149] constructs series of Cremona tables having no two fundamental points of the same order. The simplest is of order 23. The problem of the determination and location of the isolated invariant points is considered by Brigaglia.[24] The formula given by Marletta [147] does not agree with that of Doehlemann [Math. Ann. 39: 567-600 (1891)] but does agree with that of Zeuthen [C. R. 78: 1553-1556 (1871)]. The author shows how Doehlemann's result should be modified to be correct. For (1, 1) correspondences, $\rho_i=0$, $\theta_i=0$.

A complete enumeration of all types of plane Cremona transformations with not more than nine base points is given by Taylor.[216] Seven types are found.

Scott [189] presents a new method of expressing the relation between x and y near (0, 0) by means of a finite number of terms without the use of infinitesimals nor expansion in infinite series. Extensive use is made of algebraic processes.

3. Reducibility of curves under Cremona transformations. Any plane algebraic curve can be transformed into another in which all the singularities are ordinary, that is, with distinct tangents at each, by means of Cremona transformations. But by this procedure alone, real curves can not always be transformed into real curves. The necessary modifications are supplied in order to make this possible by Carnevali.[36]

The condition that one given plane algebraic curve can be transformed into another given such curve by Cremona transformations is discussed by Keller.[83] The method is to reduce each to its simplest form by Jonquières transformations, as outlined by Castelnuovo, assuming the presence of nested singularities. If $p>1$, the problem is solved. For $p=1$, $|C_{3n}|:9P^n$ is still undecided. The concept of group of Cremona transformations is that of Coble.

Williams [231] determines a transformation by means of a pencil of curves, when k base points are taken as consecutive on a given curve. The method includes that of mapping certain rational surfaces upon a plane.

4. Systems of cubic curves. The isogonal transformations of a plane cubic into itself by means of central and non-central involutions, considered as Cremona transformations of the whole plane, are discussed by Audinarayanan.[6] Elliptic functions are employed.

Further study of plane curves of genus 1 is made by Machytka.[140] Central and non-central involutions are employed to establish the results:

1) There are $4g^1_2$ and corresponding products which transform the pairs of g^1_2 into pairs of a different given g^1_2.

2) The general E and g^1_2 have four pairs in common.

3) On c_3 exist $\infty^1 G_8$ containing $3E$, $4g^1_2$ and the identity.

5. Finite groups. Finite groups of plane Cremona transformations leave systems of cubic curves through three to eight points invariant, and also the system of sextics through eight double points. There is an essential difference between those with three to six base points on the one hand and those with seven or eight on the other. For $n=7$, if the points are arbitrary, the Geiser involution is the only case possible. Similarly, for $n=8$ the Bertini involution is unique. When the base points have particular positions larger groups result (Bydzovsky[32]).

The properties of G_{16} are further developed by Machytka.[141] All three of the groups G_8, G_{16}, G_{32} of plane quadratic transformations are generated in a different way by the same author.[142] Given five points α, β, γ_1, γ_2, γ_3 in the plane. They determine a G_4, defined by quadratic I_2 with α, β, γ_i as vertices, and the other two γ_k as a pair of conjugates. The cubics of a pencil determined by these five points and by the four fixed points of γ_1, γ_2, γ_3 with α, β a pair of conjugates. The fixed points have a common first tangential, variable with the curve in the pencil. The operations of G_4 generate on each C_3 the three irrational involutions. By adjoining one Cremona transformation G_8 is generated; another generates G_{16} and finally with three, G_{32} results.

Linear systems of plane cubics invariant under a quadratic involution of the first class are given by Machytka.[143] Given a central involution, as the center describes a line a pencil $|C_3|$ results, each curve of the pencil invariant under an abelian G_8. The same author[144] applies the same methods to determine the degenerate Bertini involutions in the plane. If the eight base points P_i are such that the ninth base point of a pencil of cubics determined by them coincides with one of the points P_i, the involution reduces to the Geiser on the other seven. The pencil $|C_6| : 7P_i^2B^2C^2$, B and C arbitrary, contains one composite C_6. For ten positions of C all curves of the pencil are composite.

Marletta[146] considers a (1, 2) correspondence between the points of two planes; it is determined by eight pairs. A (2, 2) correspondence is determined by nine pairs if quadratic and by 17 if cubic.

Meyer employs a system of confocal conics to establish a quadratic Cremona transformation of lines. Associated lines are conjugate as to a certain conic of the system.[151]

The generation of certain Cremona groups by means of projective transformations and one Cremona transformation is discussed by Plamitzer.[175] The same procedure is generalized to S_3.

Theorems of closure (Poncelet, Steiner, Emch) are generalized by means of mapping circles of S_3 on points of a hyperbolic space. If a polygon X_1, X_2, . . . is circumscribed to a circle M and has its vertex X_i lying on a conic K_1, then an infinite number of such polygons exist, one for every point of the first conic K_i (Toda [218]).

That certain anharmonic ratios are preserved by Cremona transformations is extended by Sibirani [209] to apply to configurations on $C_n : O^{n-1}$ and to $C_n : O^{n-2}(2n-2)O^2$. Deaux [55] derives various properties of conics from the direct circular transformation expressed in terms of the complex numbers z, z'. Only elementary methods are employed.

Another derivation of G_{16} (for the plane) and of G_{32} (for space) is given by Moody.[165] The former is expressed in terms of cubic Cremona involutorial transformation, determined as follows: let (i, k, l, m, n) be any five points in the plane, no three collinear. Let C_i be the cubic curve through i and touching the lines $i\ p$ at p, etc. Let T_i be the cubic involution with i as vertex and leaving C_i invariant. Then $T_i, \ldots T_n$ define an abelian group of order 16, with $T_iT_kT_lT_mT_n=1$. The process can be extended to S_3 but not further, without modification.

Ciani [38] describes various geometric applications of the theory of groups of substitutions. Only linear transformations are considered; each is interpreted as a collineation.

6. Plane involutions. The Jonquières perspective plane involutorial case in which all the simple F points are consecutive to the $n-1$ fold point has been derived and the linear system of curves left invariant by it all determined by Dahy [50] in a simple well-written presentation.

An elementary property of a plane involution was given by Godeaux [96] and an alternate proof given by Deaux.[55] If (AA'), (BD), (CX) and (AA') $(BX)(CE)$ are pairs of elements of a form of the first species, conjugate in two involutions, then X is a fixed element in (AA') (DE).

Ayres [8] generalizes a method given by White [Plane Cubic Curves] to generate plane curves of order n by pairs of involutions on a line.

Curves which are transformed into themselves by plane involutorial transformations are determined by Emch.[72] Pairs of conjugate points are mapped on a surface F_{n+1} of order $n+1$, which is intersected by other surfaces also invariant and the curve of intersection determined.

An involution in the complex plane can be defined by a series of quadratic equations in the complex variable z. Let $f_i=0$ be such an equation, and λ_i a real number. Then $\Sigma\lambda_if_i=0$ defines a (1, 2) between points (λ) and points z. The two points z define an involution in the complex plane (Grace[109]).

The plane involutional transformations of order 5 are expressed in symmetric form; all the fundamental points are of the same order 2. They are therefore particular cases of the Geiser transformation $c_1 \sim c_8 : 7P^3$. They are of two kinds according to the association of conjugate F points. In one the locus of invariant points is a cubic curve, while in the other it is a straight line. Both are discussed by Bydzovsky,[28, 29] who applies it to the $C_6 : 10P^2$ left invariant.

Further properties have been determined by Sisk.[203]

Jonzon[103] discusses groups of birational transformations which leave elliptic and hyperelliptic curves invariant.

Plane involutions, order $n > 2$. The involutions of order greater than 2 are associated with Cremona transformations only when cyclic. Those mentioned here are not of that kind. de Vries[226] considers I_3 of S_2 of the first class, that is, such that an arbitrary line contains one and only one pair of associated points. Two pencils $|c_2|$, $|c'_2|$ of conics with one common base point furnish an example. As P describes a line, $P'P'' \equiv p$ envelopes a curve. There are five types, excluding those in which the points of each group are always collinear. This is followed[227] by a similar study of I_4 of the first class in the plane. The curve of coincidences is a curve of order 5 with the vertex of the pencil as triple point, hence eight tangents to C_5 can be drawn from P. They envelope a curve of class 8. Two pencils of conics and a system of $|C_3| : 5P$ furnish examples.

Sharpe[197] discusses planar I_t by means of $(1, t)$ correspondence defined by systems of curves. It is a summary only.

Pomey[177] constructs two I_3 in S_2 by means of a net of conics. Hollcroft[117] derives the defining systems of curves to generate the (3, 3) planar correspondences.

7. Quadratic space transformations. Inversion (spherical) as a Cremona transformation is discussed by Franceschi.[84] Quadratic (general) inversion is applied by Vycichlo[228] to the solution of problems in descriptive geometry, problems of contact and the construction of space curves by conjugate projections. Besides the tangents at particular points, the osculating conic must be known.

Meyer[152] applies quadratic inversion to problems in closure, generalizing from S_2 to S_3. Given a quadric surface as a point locus and a space cubic curve. Consider a tetrahedron inscribed in the surface, circumscribed to the curve (and dually). There are 12 linear equations of condition, giving one general solution. If more than one exists, then there are ∞^2 solutions.

A quadratic transformation in S_3 is determined by two F points and four pairs of conjugate points, or by four fixed points, the F cone and the principal plane (Mikan[158]). The same author considers a (2, 2) Cremona correspondence in S_3 and its inverse. A bundle of lines is transformed into ∞^2 conics, ∞^1 of which meet their associated lines. The point of intersection generates a space quintic curve of genus 2. A complex $|C_5|$ is defined by ∞^3 vertices. The complex has seven base points. The $|C_5|$ through a point generate a cubic surface. The curves are isologues for ∞^3 Cremona transformations.[156] The (2, 2) Cremona correspondence of S_3 has six fixed points, hence imposes 18 conditions. ∞^8 have the same fixed points. One can be constructed by 12 pairs of points.[155]

Cubic transformations. The (3, 3) Cremona transformations defined by three bilinear equations are classified into 24 varieties by Pobanz.[176]

Vaidyanathanaswami[224] gives an elaborate analysis of cubic transformations associated with a desmic system and applies the results to plane geometry.

8. Hyperspace transformations. Given two pencils (A), (B) in the plane (x) and (A'), (B') in (x') in projective correspondence. If they have only one variable intersection, the process determines a plane Cremona transformation. In the plane every Cremona transformation can be generated in this way. It may also be applied to higher dimensions (Glagoleff[91]).

The G_{32} of correlations and collineations on the Kummer surface (Klein's group) is studied in connection with the general quadratic line complex by Bouligand.[22]

The Cremona group isomorphic with that of the 27 lines on a cubic surface (Black[18]) is a direct generalization of Coble's $G_{n'}$. Coble's P_6^2 of the $G_{6'}$ of S_4 is generated by adjoining the inversion $x'_i=1/x_i$. The $G_{6,2}$ is obtained, isomorphic with the group of the 27 lines of the cubic surface. The order for each transformation for $n=6$ and $n=7$ is found.

Reduction of algebraic surfaces. Geppert[89] gives a basis of classification of algebraic surfaces according to genera and plurigenera into three categories, (a) $P_{24}=0$, (b) $P_{24}=1$, (c) $P_{24}>1$. The first includes those reducible to rational ($p=0$) and irrational ruled surfaces; (b) those having pluricanonical curves of order zero; and (c) those with proper canonical and pluricanonical curves. If $p^{(1)}>1$, each can be reduced to a definite normal form in hyperspace. Godeaux[108] enumerates unsolved problems in algebraic geometry and suggests that the most important are:

A. Determine the conditions for rationality of an algebraic variety of three dimensions.

B. Classify the involutions belonging to three space.

C. Determine whether the general cubic hypersurface of S_4 is rational. *See also* Snyder.[205, 210]

Godeaux[98] continues his study of surfaces of genera zero and of bigenus 1. The images of sections of F_4 and of F_8 are mapped on S_9. It is shown that the Jacobian of a general web of quadrics is birationally equivalent to a double quadric having a curve of branch points of order 8.

Hudson[122] mentions that many of her results[121] concerning incidence relations for Cremona space transformations had been anticipated by Montesano.[161]

Conte[45] gives an extension of del Pezzo's Cremona transformation in which planes are transformed into quadric cones, to cones of order n having an $(n-1)$-fold base line with $n-1$ fixed tangent planes and $n-1$ isolated points. The feature is the existence of homaloidal systems with variable multiple points.

Conte[46] gives the detailed description of a quartic surface obtained by transforming a general quadric by the (2, 2) Cremona transformation in which the image of a plane in each system is a quadric cone with a variable vertex. The same author[47] gives similar details concerning the transformation of a general cubic surface by the same transformation, and adds the effect of the presence of $1-4$ nodes on the given surface.

9. Special transformations in S_3. Albanese[2] extends his researches of plane algebraic curves to surfaces. By means of a certain system of curves on the surface F, it can be transformed into a surface of S_r with only multiple curves and simple multiple points. Then by a finite series of quadratic transformations, a surface still in hyperspace is obtained, having no singular points.

Formulas in S_3 analogous to those already known for the plane were found by Hudson,[120] including the theorem of Tummarello[228] that the genera of irrational fundamental curves are the same in S_3 and S'_3. The 31 formulas given include F curves of the first and second species but do not include condition of contact. The latter can be removed by Levi's theorem [Atti di Torino 33: 56-76 (1897)].

Various special Cremona transformations of S_3 are concerned with restricted systems; thus, Dohogne[59] gives a synthetic treatment of a transformation that transforms the congruence of bisecants of a space c_3 into a similar congruence for c'_3. $\Phi_{2n+1} : c_3{}^n \sim c'_{2n+1} : c'_3{}^n$.

10. Fundamental elements. Piazzolla-Beloch[179] treats those transformations that have only one fundamental curve of the first kind. Let $f_m{}^{(i)}$ on $|\phi_\mu|$ be the only multiple curve. If $i > \mu/4$, there are only a few possible forms, but if $i \leqq \mu/4$, and f is not a straight line, f must lie on a cone, with vertex at a fundamental point and each generator meets the curve once. If T and T^{-1} each have only one fundamental curve, T can always be reduced to the monoidal type.

Godeaux[94] makes an extensive study of fundamental curves of the second kind. The tangent planes to the surfaces $|\phi_m|$, images of the planes in the other space, may be all variable, while in the other space they may be all variable, part of them fixed, all fixed along the image curve. A new proof is given that if one fundamental curve of the second kind is of multiplicity r, its image is of order kr; if one in the second space is of multiplicity s, and its image of order $k's$, then $k=k'$ This theorem was first proved by Montesano.

The essay of Stuyvaert[215] is first concerned with quadratic and reciprocal transformations in S_n, and then sketches some (1, 1) transcendental transformations.

The stereographic generation of the Jonquières S_2 transformation is treated by Tinto.[217] A ruled surface of order n and having an $n-1$ fold line is given. Two points on it are taken as centers of projection. A point in a given transversal plane is projected upon the surface R_n from one of them and this image point on the surface is then projected back upon the plane from the other.

A further study of the behavior of a homaloidal web of surfaces along a fundamental curve of the second kind is given by Torrey.[222]

Sharpe[196] points out errors in the paper of Godeaux on the Jonquières space transformation.

The cubic line complex associated with the involutorial [3, 3] transformation is mapped on the points of S_3 by Horsfall.[119] Two quadratic and the general linear complex are included as composite forms.

Burniat[26] considers certain fundamental points of space Cremona transformations. Let $|\phi_m|$ of S_3 have a fixed cone at a point O, of multiplicity p, and ∞^2 have O to multiplicity $p+1$, with variable tangent cones. Then T must be monoidal and each cone must have a generator of multiplicity $p-1$. Equations of T are derived but the discussion is synthetic.

Coble[42] discusses the behavior of the rational plane sextic curve and its related Cayley symmetroid under regular Cremona transformations. Under Cremona transformations C_6 has only a finite number of types; with each is associated a symmetroid.

Let I_2 be an involution of pairs of points P_1, P_2 in S_3 and V_3 the map of the involution. Let Γ be a fundamental curve of I_2 such that corresponding to any point P the image is the whole curve. Hence Γ com-prises ∞^2 pairs of points P_1P_2 and its image is a surface Φ on V_3. But every point of Γ has itself among its images, hence is a coincidence. The image is therefore on the locus of branch points on V_3.

If $\pi \sim \Psi$, the system $|\pi+\Psi|$ of order $n+1$ is invariant under I_2. The individual surfaces $\Sigma\pi_i\Psi_i$ belong to this system and are themselves invariant. If I_2 is rational, V_3 is rational. Since Γ is rational, the image surface Φ is rational.

The multiplier λ of Montesano is such that the multiplicity s of C on $|\Psi|$ and its order ν are connected by the relation $s=\lambda v$. The curve on Φ as curve of branch points is of order s (Godeaux[106]).

The theory of isolated fundamental points is continued in.[105] Consider F points with variable cones of a pencil for images. $F_n: O^{pq}$, $q \geq 1$, tangent cones $|\Gamma|$ composite, q cones G of a pencil $|G|$. $|\Gamma|$ is of dimensionality 2 or 3. Points in the domain of the first order are transformed into rational curves Γ'_q, points on Γ' are images of generators of the same cone G. Γ'_q is multiple, $p-1$ fold on $|\Gamma'|$ and part of the components of $|\Gamma|$ may be fixed. The transformation may be monoidal.

11. Reduction of surfaces by Cremona transformations. The classification of algebraic surfaces from the standpoint of birational transformations (not Cremona transformations) is proposed by Enriques.[74] Let π be the genus of a plane section, p_g, p_a, P_i have the usual meanings. Ruled surfaces can be transformed into cylinders $f(x, y)=0$ of $P_4=0$, $P_6=0$. Hyperelliptic surfaces $\begin{matrix} 1 & 0 & g & h \\ 0 & 1/\delta & h & g' \end{matrix}$, $p_a=-1$, $p_g=P_4=1$, δ is the divisor, ∞^3 surfaces existing for each value 1, 2, . . . of δ.

If $p_a=P_4=1$, the surface is regular with no proper canonical curve $z^2=f_6(x, y)$, and an F_4 and F_6 of S_4 are examples. If $P_4+P_6>1$, $p^{(1)}=1$, and ∞^1 families exist; if $p^{(1)}>1$, only a finite number of families exists. Multiple planes with various curves of branch points are considered, also integrals of exact differentials and existence criteria.

The system of invariants under a general birational transformation of an algebraic curve, and the smaller set under linear transformations are both known. Are there invariants for a Cremona transformation? Coble[43] points out that, in addition to the canonical C_{2p-2} of S_{p-1} for all birational transformations, for a Cremona transformation there is also a particular rational surface ϕ on which lies the non-hyperelliptic canonical curve. *See also,*[44] p. 23-64.

12. Tables of characteristics. In case a Cremona transformation of S_3 is regular, that is, has no contact conditions along base curves and no fixed tangent cones at isolated fundamental points, it is possible to construct two tables of incidence, analogous to those of Cayley for

Cremona transformations in S_2. This is particularly explicit, provided the given transformation has no fundamental curves of the second kind.

Let $O_1, \ldots, O_{h-1}$ be isolated base points, and $O_h, \ldots, O_p$, the system of base curves of a homaloidal system. Let a surface π be of order n, have each O_k to multiplicity x_k and O_i to multiplicity x_i, $k<h$, $i \geq h$. Then we may write

$$\pi : n x_1 \ldots x_{h-1} ; x_n \ldots x_p .$$

These numbers define the characteristic group for the system of elements $O_1 \ldots O_{h-1} O_h \ldots O_p$. Similarly for each fundamental surface of the first kind (image of a base curve) or of the second kind (image of an isolated F point). This is table A. In the same way, a table B for a curve, image of a line and of each principal curve can be constructed. In (x'), $A'=B$ and $B'=A$, if horizontal and vertical rows are interchanged (Montesano[161]). If only one fundamental curve exists in each space, the two genera are equal.

Similarly, if all the fundamental curves in one space are rational, those of the other are also rational. The sum of the number of base points and base curves is the same in both spaces.

It was then proved by Tummarello[223] that the genus of each fundamental curve in (x) is equal to that of a certain fundamental curve in (x'). The determinants A, B have the property that the reciprocal of A is B, and the reciprocal of B is A, hence all four determinants which define incidence of curves or of surfaces in each space with its fundamental elements are known when any of them in either space are given.

These properties were all found independently by Hudson[120] by a partly different method,[121] p. 206.

13. Series of composition. The fact of the incidence tables giving so much information concerning a regular Cremona transformation of S_3 suggests something analogous to series of composition. Various cases of this are known. Montesano[163] constructs such a system, different from those already known. Start with the (3, 3) Cremona transformation whose base elements are four skew lines r_i and their two transversals u, v. The latter are fundamental lines of the second kind. The inverse is of the same form r'_i, u', v'. A line meeting u, v is transformed into a line meeting u', v', hence the point ranges on such lines are projective. Moreover, the points (r, u) and (r, v) are transformed into the points (r', u') and (r', v') and the projectivity can never be degenerate. Now consider the product T_1 and T_2, such that if T_1 is defined by (u_1, v_1) (u_2, v_2), then T_2 is defined by (u_2, v_2) (u_3, v_3). The fundamental lines r_i of the first kind may all be different or partly the same, hence the order of the product may have different values. The properties of the lines (u_1, v_1), (u_3, v_3) are as before, except that, given a point on u_1 and one on u_3, there may be two lines passing through these points and be images one of the other. Similarly for any number of such component T_i. Conversely, given a T determined by two skew fundamental lines u, v of the second kind, and all the other base lines consisting of lines of the congruence u, v of various multiplicities. If u, v enter symmetrically, then the transformation is expressible as the product of T_i as defined above. In one sense this is analogous to a generalized monoidal transformation. In the regular monoidal transformation a bundle of lines is transformed into a bundle. Here a linear line congruence is transformed into a similar congruence (with distinct directrices). But such a congruence can be transformed into a bundle.

A rational three dimensional variety, representable on S_3 in two different manners, establishes a Cremona transformation between two linear spaces S_3, S'_3. By considering sections and their plane representations, most of the Cremona transformations in which the homaloids of one or both systems are cubics are obtained (Semple [193]).

14. Cremona transformations in hyperspace. The general theory rapidly becomes complicated as the number of dimensions increases. The types involving quadrics in one system have been completely enumerated. Semple [194] gives the detailed study of the (2, 3) case in which the base is an elliptic quintic curve of S_4. In the inverse, the homaloids are Segre 10-nodal cubics, the intersection of two of which is the projection of the quartic Veronese surface of S_5. The base of this system is a quintic surface. The highest order of the inverse, when one system is composed of quadrics, is 7.

A particular (4, 4) transformation of S_4 associated with certain projectively generated loci is given by Todd.[219] Given 5 points A_i in S_4, vertices of projective systems of $|S_3|$. A symmetric (4, 4) Cremona transformation is generated by them. It can also be expressed by four bilinear equations and includes the reciprocal case $x'_i = 1/x_i$.

In Cremona transformations of S_r defined by systems of bilinear equations, the base is expressed by the vanishing of several determinants of a matrix. Given a matrix of p columns, q rows, each element a linear function of the point coordinates in S_n. The locus defined by the vanishing of all the determinants of order p has the freedom $pq(n+1) - p^2 - q^2 + 1$ (Room [183]).

When each of the bilinear equations $\Sigma a_{ik} x_i x'_k = 0$ has every $a_{ik} = a_{ki}$, the transformation is an involution. The case $n = 4$ is considered by Alderton.[3] The description of $|M_3^4|$, conjugate of the $|S_3|$ of S_4, was added by Wong.[158]

Given five planes π_i in S_4; relate the systems (A_i) to them so that sets of corresponding S_3 intersect in these planes. The homaloids then contain the planes. The $M_4^{(4)}$ through all the planes π_i form a homaloidal system and they are all determinantal. That of Veneroni [Lomb. Rend. (2) 34: 640-644 (1901)] is an example. This form may also be defined as the direct generalization of cubic surfaces in S_3 through four skew lines, the transversals u, v then being fundamental lines of the second kind. The $V_4^{(4)}$ through 5 planes form a homaloidal system, the transversals of the planes forming a system of the second kind. It can be generalized to the V_r determined by $r+1$ S_{r-2} as base (Snyder[210]).

For the cubic Cremona transformation a more extensive study of the intersections of cubic hypersurface in S_4 must first be made. A first step in this direction has been taken by Semple.[192] When composite, the residual intersections and the curves of intersection of the components are also discussed. In terms of these a homaloidal system can be built up. Only the main categories of forms are considered.

Archbold[4] derives the involutions of S_3 by means of projections of the involution in S_4 formed by linear systems of quadrics. Two methods are possible: (a) obtain $|H_2|$ of grade 2 and freedom 4, which requires postulation and equivalence, not completely developed for S_4; (b) get the intersection of two quadrics of the system; it is always rational. This can be mapped on a plane; then get the residual intersection $|c|$; then on $|c|$ find systems of grade 2.

The use of Cremona transformations of S_r, $r>3$ to transform surfaces with singular curves and singular points into surfaces having neither has been made by Babbage,[10] who discusses 16 surfaces in S_3 in detail. The Segre-Zeuthen invariant and the Severi invariant, as well as the genera of the surfaces, play the most important part, $I=\mu_2-2\mu_1+3\mu_0-4+\Sigma s$, $\omega-1=\mu_2+v_2-6\mu_1+9\mu_0+\Sigma s(2s-3)$; $\mu_0=$order, $\mu_1=$rank, $\mu_2=$class of the given surface; v_2 is the number of pinch points on multiple curves, s the number of isolated multiple points. A number of properties which contribute to the study of the cubic variety in S_4 are given in.[212] Thus:

Given V_3 of S_4 and a line l not lying on it. Let M be one of the points in which l meets V. A point P of S_4 determines a plane Pl, meeting V in a cubic curve through M. Let M' be the first tangential of M as to this curve. The line $M'P$ meets the polar quadric of M' as to V in M''. The harmonic conjugate of P as to $M'M''$ is P'.

The transformation $P\sim P'$ is involutorial and leaves V invariant. The locus of M' is the cubic surface γ, intersection of V with the tangent space at M.

If l meets V in M, N, P, the three involutions I_M, I_N, I_P generate an infinite discontinuous birational group, leaving V invariant. Each I transforms S_3 into a V_8.

Given two skew lines l_1, l_2 both on V, and a plane π not on V. Given a point y. The $S_3=\pi$, y meets l_i in P_i. The line P_1P_2 meets V in K. The line yK meets the polar quadric of K as to V in K'. The harmonic conjugate of yKK' is y'. This is also involutorial.

Given a line l on V and a rational surface R_n not on V, having $n-1$ points on l. A point (y) determines a plane y, meeting R_n in one point P. The plane meets V in a conic C_2. Let p be the polar of P as to C_2. The conjugate of y in the harmonic homology P, p is y'. It generates an involution leaving V invariant.

Williams [232] defines a transformation of the lines of S_3 by means of two quadratic reguli. A line t meets two lines of each and these have another transversal. The system is involutorial. The same problem was considered simultaneously and from nearly the same point of view by Clarkson.[40] Mapped on the points of a quadric hypersurface of S_5, each defines a non-linear transformation under which Ω remains invariant.

The monoidal Cremona transformations of S_4 are discussed by Franceschi [82, 83] with numerous analytic details.

Wong [236] generalizes the quartic transformation between two planes by means of the bisecants of a space cubic curve to T_{r^2} between S_r, S'_r, by means of a ruled manifold of $r-1$ dimensions in S_{r+1}.

15. Invariants of surfaces and of varieties. The general theory of transforming a given algebraic curve into another having no multiple points is given by Albanese.[1] Given $f_n(x)=0$, genus p. Cut it by $|\phi|$, $\lambda>n-3$, in $g_m{}^r$, $r=\lambda n-\dfrac{(n-1)(n-2)}{2}$, $m=\lambda n$. In $g_m{}^r$ is contained $g_{m_1}{}^{r-1}$, $m_1\leq m-2$, and this contains $g_{m_2}{}^{r-2}, \ldots, g_{m_s}{}^{r-s}$ for every s for which $r-s>2$. The proof is claimed to be simpler than that of Severi [Ven. Atti. 79:933-943 (1920)]. By projecting the transformed non-singular curve upon a plane, one with only ordinary multiple points (with distinct tangents) is obtained.

Fano [77] continues his studies of algebraic varieties of three dimensions that are regular, having all genera zero and invariant under a continuous group of birational transformations. He shows that such varieties are either rational or can be mapped upon a cone projecting a surface on which $P_3=0$, $P_2>1$. An involution of S_3 is rational or irrational according as it admits, or not, a continuous group of birational transformations, having a finite number of continuous parameters.

By means of two planes in S_5, Edwards[68] derives the periodic (2, 2) correspondences between two planes. The V_3 of joining lines of corresponding points is cut by S_4. The section is a surface invariant under two birational correspondences. The conditions for periodicity are then derived.

16. Involutorial transformations in S_r, $r \geq 3$. The enumeration of involutorial Cremona transformations given by Sharpe and Snyder[198.1] excluded monoidal types and also those having contact along a fundamental curve. Godeaux[100] considers further various I discussed by Sharpe and Snyder; $|F_4|$ with a single base curve may be defined by congruences of elliptic $|C_4|$, intersections of homologous quadrics of two homologous nets, each with eight base-points. Babbage[9] develops an extension of the same process to higher spaces, such that by projection contact conditions in S_3 can be secured. Given a complete system $|\Phi|$ of hypersurfaces in S_r such that r members of the system meet in two variable points, and a rational variety in S_n.

Two spaces S_{n-r-1}, S'_{n-r-1} can then be constructed such that $|S_{n-r}|$ through S_{n-r-1} meet the rational variety in one point, and $|S_{n-r}|$ through S'_{n-r-1} meet it in two points. If these are cut by S_3, S'_3 respectively, a (1, 2) correspondence is defined. Sections by S_{n-r} contain prime sections of $|\Phi|$. All I_2 defined by cubic surfaces of grade 2 are found. These include ten new ones having contact conditions.

Schoonmaker[188] discusses a non-linear point-plane duality on points of a cubic surface. By using a pencil $|F_3|$, an involution transforming the planes of space into surfaces of order 11 is obtained. Every conic of a linear congruence is transformed into itself. Two similar involutorial transformations, one of order 9 and one of order 11 are developed by the same methods by Snyder and Schoonmaker.[212]

Following a suggestion proposed by Montesano in 1888, Purcell[178] defines certain involutorial Cremona transformations between two spaces S, S' by means of two linear line congruences G in S, G' in S' connected by a birational relation θ, and a reciprocity ϕ between S and S'. Through a point P of S passes a line g of G, to which corresponds a line g' of S' defined by θ. The line g' is cut by π, image of P in ϕ, in P', conjugate of P. Some particular cases of this transformation, in which only a finite number of invariant points appear have been developed by the same methods by Godeaux.[107]

A series of involutorial transformations of space can be generated by a pencil of surfaces $|F_n| : d^{n-2}$, the points on the line being made projective with the surfaces of the pencil. A point P in space determines the surface of the pencil passing through it and this in turn a point D on the rational carrier d. The line PO meets the surface determined by P in P', its conjugate in the transformation. The (1, 1) correspondence can be replaced by $(k, 1)$. The simplest case is that of pairs of planes and points of a line. The case $k=1$ gives a transformation of order 3. This is always rational (Dye [66]), although Montesano strongly was of the opinion that the process included irrational involutions (Snyder [207]). A similar process is applied to obtain those involutorial transformations in S_3 in which the conjugates of planes are $F_n : d^{n-1}$. The equations and the maps of all such involutions are obtained by Dye.[66] The I_4 defined by webs of quartic surfaces with a basis double conic are derived by Dye and Sharpe,[67] thus supplementing and completing those derived by Aroldi.

Sharpe [197] derives the equations and a map on S'_3 of the involutorial transformation obtained and described by Montesano but only for the case in which the planes through the $n-2$ fold line are paired in an involution. That in which each plane is invariant is not discussed.

Lairesse [137] discusses an I_3 determined by polarity as to a net of quadrics through a space cubic curve and a system containing a line. All are included in the general bilinear system, but various properties are more easily determined by the particular cases.

The tetrahedral I_{19} is treated from a slightly different stand point by Godeaux.[100] In a later paper by the same author,[101] three other cases already derived by Sharpe and Snyder are studied by the same method. The I defined by the web of quadrics through six points has been studied further by Bolus [19, 20] when the points approach coincidence in various ways. A systematic discussion of all the cases is made by Hyden.[124]

17. Involutions defined by a $(k, 1)$ correspondence. The projectivity between the quadrics of a pencil and a pair of generators on another as first considered synthetically by Montesano [Rom. Acc. L. Rend 4: 171-178 (1888)] with the equations and numerous properties added by Davis [51, 52, 53] is replaced by a $(k, 1)$ correspondence by Snyder [207] and the system mapped on hyperspace. The same idea is applied to $|F_n| : d^{n-2}$, in which d is a straight line and the residual is noncomposite, by Carroll.[30] For $n=2$, this gives a generalization of a type synthetically discussed by Montesano [Giorn. di Mat. 3: 52-64 (1893)]. The congruence of bisecants of the elliptic quartic curve, base of the pencil of quadrics, is left invariant. For $n>2$ various fundamental straight lines of the second kind appear, each one illustrating Montesano's theorem [Rom. Acc. L. Rend (5), 18: 421-427 (1921)]. Every plane through d is invariant; in each the plane involution is of the Rufini type in which every conic of a pencil remains invariant and a number of simple base points are collinear. The case of the residual base curve being composite is considered by Rusk.[185] A wealth of new configurations of fundamental lines of the second kind is shown.

When the $(n-2)$-fold base line of the pencil is a curve, the number of forms is restricted. This was considered by Black,[16] restricting the residual curve to be noncomposite. A fundamental curve may be both of the first and of the second kind. In a second paper[17] the cases of composite residual curves are all included.

When all the surfaces of the pencil are ruled, the generators through the associated point on the directrix (necessarily rectilinear except in a few cases) are all parasitic and the surface generated by them is a factor of every homaloid. All the surfaces of the proper homaloidal web have the same tangent planes along the residual base curve as those of the surface removed. The transformations furnish examples of the largest contact conditions compatible with a homaloidal web (Snyder.[209, 210])

Involutions in hyperspace. The study of cyclic involutions is extended to three dimensional varieties by Godeaux.[99] The image of a coincidence is a four-fold point on the image variety of the involution. The hyperplane sections of the tangent hypercones is a surface of Veronese for I_2. For the cyclic I_3 either the image of a coincidence is a four-fold point, sections of the tangent hypercone being a rational normal ruled surface of order 4, or it may be a nine-fold point, the associated surface being the image of the system of all plane cubic curves.

James[127] corrects a statement in a previous paper[126] concerning involutions on a normal rational quartic curve. Any I on C_4 can be obtained by one procedure, by means of $\infty^3|S_2|$ each meeting C_4 in three points; *see also* Segre [Rom. Acc. L. Rend. (5), 18: 22-30 (1921)].

18. Involutions on V_3^3 of S_4. The involutions of the general cubic variety of S_4 are important in the study of the rationality or nonrationality of the variety. Four new involutorial transformations were found by Snyder and Lehr[211] which generate infinite discontinuous Cremona groups belonging to the variety, but which do not admit continuous transformations.

Snyder[205] maps V_3 of S_4 doubly on the points of S_3 and discusses various I of S_3 belonging multiply to a linear line complex. Various forms of infinite discontinuous groups are generated which leave V_3 invariant. The general Cremona transformations of S_4 are discussed by Archbold.[5] Isolated points ~ primals; points may go into surfaces or curves and curves ~ primals, surfaces or curves. This is illustrated by (3, 3) transformations defined by bilinear forms.

The invariant loci of the Cremona transformations defined by $x_i = 1/y_i$, wherein y_i are linear functions of x_i, can be expressed in terms of $\pm 2^h$ fixed points arranged in $\binom{h}{2}$ pyramids of 2^{h-1} vertices, each inscribed in the other. Multiply perspective cases were considered by del Re.[181] Inversion as to systems of quadrics in $[h]$ is defined by polarity, with special reference to $h=3$ by del Pezzo.[178]

Let x_i be the non-homogeneous coordinates of one space, y_i, of another joined by $y_i = (a_i x_i + b_i)/(c_i x_i + d_i)$. If $c_i \neq 0$, this can be reduced to inversion by linear transformations; if $c_i = 0$, to identity. It is a generalization of the T_{tet} of Hudson. For $n=3$, interesting conical quadratic types result (del Re [182]).

19. Polarities in S_4. Given four quadric primals in S_4. The polar S_3 of a point meet in a point. An $S_3 \sim \Omega_3^{(4)} : V_2^{10}$. A point of the base line $C_1 \sim C_4$ but if C_1 meets V_2^{10} in r points, r lines come off as components of image C_4. Ω is mapped on S_3 by means of surfaces through intersections of S_3 and V_2^{10}. The base curve is γ_{10} of genus 11, residual being C_6, $p=3$ (Roth [184]).

Wong [233, 237] discusses further properties of Cremona transformations defined by polarities. The first is concerned with the image of a plane in S_r, with more details for $r=4$. The second defines a point-line transformation in S_4 by means of three quadric polarities. Points of a line $\sim$ lines of a cubic ruled surface; points of a plane $\sim$ lines of a V_3^3 whose sections by arbitrary S_3 is a general cubic surface.

By projecting the image of a plane in a [4, 4] of S_4 defined by polarities upon S_3, a sextic surface with a double curve of order 7 is obtained (Wong [234].)

20. Cremona transformations connected with line complexes in S_r. Given an $r-1$ complex Γ of ∞^{r-1} lines in S_r, one line through every point. It may be generated by secants of linear spaces or of rational varieties. A Cremona transformation of S_r can be defined by two primals Σ, Σ', points P, P' belonging to same line of Γ. Hyperspace transformations may be interpreted by lines. Any transformation that leaves the quadric $V_2^{(4)}$ of S_5 invariant can be interpreted as a transformation of lines of S_3. Clarkson [35] considers four pencils of lines in four different planes. A line t meets a line of each pencil, and these four skew lines have a second transversal t'. The involutorial transformation (t, t') is then interpreted in terms of points. Two of the pencils can be replaced by a quadric regulus, or all four by two such reguli.

The same process [41] is applied to a ruled cubic and a pencil of lines and to a ruled quartic surface having a proper double cubic curve and no rectilinear directrix. The latter has a linear involutorial transformation in S_5, the transversal t' being the conjugate of the given one as to the linear complex to which the given ruled quartic belongs. Another variation is given.[41] Given two plane Cremona transformations H_a in the plane a, H_β in β. Let $A \sim A'$ by H_a, $B \sim B'$ by H . A line t meets a, β in A and B. Then t' is defined as the line $A'B'$.

A line to line Cremona transformation in S_3 is defined by two pencils of quadrics by Snyder and Clarkson.[218] Given a fixed plane π. An arbitrary line p is bisecant of a single C_4 of the system and meets π in P; through P passes a second bisecant p' of the same C_4. The involution of $p \sim p'$ has the property that the lines of each conjugate pair intersect.

Haenzel [111] considers transformations of linear line congruences by means of polar S_3. Only collineations and correlations are included. A more extended use of polarity is made by Jolles.[129] Minute study is made of the differences arising according as directrices are real or imaginary. The characteristic numbers arising from such transformations of lines are determined. Three characteristics appear as analogous to class. If all three classes are each equal to one, the lines meet two fixed arbitrary planes. The procedure is interpreted in terms of points on $V_2^{(4)}$ of S_5.

Beck [12] considers involutorial transformations in conformal space. Lines are mapped on points, with a metric interpretation of points on a quadric hyperplane of S_4. It is applied to various cases treated projectivily by de Vries, Clarkson, etc.

21. Cyclic involutions of order $n>2$. In a series of notes Godeaux [101, 102, 108] considers involutions belonging to algebraic surfaces. Every such involution is generated by a birational transformation that leaves the surface invariant. An invariant point is said to be perfect or imperfect, according as the projectivity of associated directions through it is the identity or not. This difference furnishes the principal basis of classification, when the point is transformed into an exceptional curve. Various particular cases are studied in detail, $n=11$.

Certain algebraic space curves can be generated by means of involutions. Given two cubics C_3, C'_3 in S_3, with $[C_3, C'_3]=0$. Let G_1, G_2 be their congruences of bisecants. If a (1, 1) correspondence between G_1, G_2 be given, then a curve is defined as the locus of the point of intersection of ∞^1 conjugate bisecants. Given two projective bundles of lines, a C_3 is generated in this way. This can be generalized to a rational congruence defined by a line and a rational C_n meeting the line in $n-1$ points. If the Cremona transformation is a projectivity, the order of the curve is n_1+n_2-2.

Browne [25] discusses the algebraic problem when the product of two involutions in S_n is an invariant. No geometric applications are given.

22. Double planes. A surface which can be written non-homogeneously in the form $z^2 = f(x, y)$ is called a double plane. The curve $f(x, y) = 0$ in the plane $z = 0$ is its curve of branch points.

Campedelli[84] considers those in which the curve of branch points is of order 10 and finds 28 types of surfaces birationally distinct. Among them are:

1) If p of C_{10} is 36, $p_g = p_a = 6$, $P_2 = 15$, canonical curves are hyperelliptic and represented by double conics.
2) $c_{10}: P_9$. Surface is ruled, $p_a = -4$, $p_g = a$.
3) $c_{10}: P_8$. Rational.
4) $c_{10}: P_7$ (or P_6). $P_2 = 5$, $p^{(1)} = 1$.
5) $c_{10}: P_4 P_6$. $p = 2$, $p^{(1)} = 1$, $P_2 = 3$. Similarly for $c_{10}: P_7 P_3$.
6) $c_{10}: P_7 P_3$. Reducible by quadratic transformations $p_a = P_2 = 1$.

The same author[38] discusses double surfaces having a curve of branch points of order 8. If C_8 is non-singular, $p_g = p_a = p = 3$, the canonical curves are hyperelliptic and are represented by lines on the double plane, $P_2 = 6$.

$C_8: P_4$, $p = 2$, $P_2 = 3$. $C_8: 2P_4$, $p = 1$, $P_2 = 1$. These types were found by Enriques [Mem. Soc. It. (3) 10: 1-106 (1896)]. C_8 is reducible to a particular C_6 and two lines, $p_a = p_g = 0$, $P_2 = 1$. This case, found by Enriques, has been studied extensively by Godeaux [Brux. Bull. (5) 13: 114-133 (1927)]. Several properties have been found by Johnson,[84] who provides alternate proofs and various corrections to the results of Godeaux.

Canonical system compounded with an involution. On an algebraic surface Φ, if the canonical system $|K^*|$ is not invariant under Γ, then (a) within $|K^*|$ are two linear systems $|K_1^*|$, $|K_2^*|$ compounded with Γ, of dimensions r_1, r_2 such that $r_1 + r_2 + 2 = p_g$; (b) every special complete linear system, invariant in Γ is contained totally or partially in $|K_1^*|$ or $|K_2^*|$. If Γ has D fixed points, then (c) if π_g is the geometric genus of the image F of T on Φ, either $|K^*|$ is invariant in Γ or $|K_1^*|$ has the dimension $p_g + 1$, $|K_2^*|$ has the dimension $p_g - \pi_3 - 1$. (d) If $\pi_g = 0$, then $|K^*|$ is compounded with Γ (Maroni[148]).

23. Montesano's multiplier. The theorem of Montesano [Rom. Acc. L. Rend. (5) 27: 396-400 (1918); 30: 447-451 (1921)], that the multiplicities of fundamental curves of the second kind in S_3 of orders m, m' are respectively, $\lambda m'$, λm, in which λ is a positive integer, has been generalized by Marletta[145] to apply to extensive categories of Cremona transformations in S_n.

Given a Cremona transformation T between the points of S_n, S'_n, both contained in the same S_{2n}, and also two spaces O_{n-1}, O'_{n-1} of $n-1$

dimensions. A point P in S_n determines a primal Σ_n through O_{n-1}. Its image P' determines Σ'_n through O'_{n-1}. Let the locus of the intersection Σ_n, Σ'_n be a primal Ω.

If a point F in S_n has the property that Σ_n determined by F and O_{n-1} meets Ω in a variety ψ which is λ fold on Ω, then the variety ϕ' obtained by projecting ψ upon S'_n from O'_{n-1} has the property that each of its points is the image of F. If ϕ' is of dimensionality k, F is said to be a fundamental point of the species k.

Emch[79] defines an involutorial Cremona transformation of S_r by means of a series of quadratic systems $a_r\lambda_r^2+b_r\lambda_r+c_r=0$ of primes.

24. Generalization of types of involutions from S_2 to S_3. Space involutorial transformations represent generalizations of the four types of plane involutions in two ways. If I in space leaves a rational surface F invariant, then the plane map of F has this property and the map is invariant under one or another of the four types. Examples of this are given by Godeaux[100] and by Snyder.[205] If in I each plane of a pencil is invariant, the space involutions of this category may be classified according to the nature of the transformation in each plane. Examples of the Geiser type are given by Carroll[37] and Rusk,[185] those of homology by Snyder,[204] the Jonquières type by Purcell[178] and those of the Bertini type by Snyder and Lehr[211] and by Godeaux.[104]

The last case has been more extensively developed by Sharpe and Dye.[198] Given a cubic surface F and two fixed points O_1, O_2 on it. A conic is uniquely fixed by a point P and touching F at O_1 and O_2. It meets F in P', conjugate of P in I. Each plane through O_1O_2 is transformed into itself. If F is mapped on a plane, the plane map of I is an involution of the Bertini type. Let O_3 be the third point of intersection of the line O_1O_2 with F and O_P be the tangential of O_3 in the section of F by the plane O_1O_2P. The line PP' passes through O_P (Snyder and Lehr[211]). When the cubic surface describes a pencil, the transformation is defined for S_3 (Black[16]). The points O_1, O_2 may be both fixed or one or both describe rational curves projective with the pencil. The process is then carried into S_4 by means of nodal V_3.

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CHAPTER V

MULTIPLE CORRESPONDENCES

VIRGIL SNYDER

Multiple correspondences in the plane and space have had in view the (a) method of generation, (b) the curves of branch points and (c) neutral elements.

1. (1, n) correspondences. de Vries[83] generates an I_4 in S_2 by means of two pencils of conics and by systems of cubics. The latter as given is incorrect. The curve of coincidences is $C_5:P^3$, class 14. The tangents from P envelope a curve of class 8. The same author[82] gives an I_3 of S_2, such that an arbitrary line contains one pair of associated points. It can be generated by two pencils of conics with a common base-point. As P describes a line, the line joining its associates envelopes a curve of class n. There are five types, other than those having triads of collinear points.

In a net of conics, one curve of the system exists having a given line of the plane for principal axis. Two principal axes determine a Cremona involution, the line being the element. These include a particular Geiser involution and a Jonquières of order 4. An interesting metrical case is furnished by conics touching the sides of a triangle. The cases mentioned are now produced as the product of three quadratic transformations, which generate an abelian group of order 8 (Rao[59]).

The (2, 1) correspondences between two complex planes is defined by $fw+f'=0$, f and f' being quadratic in z. By it circles are transformed into bicircular quartic curves. It can be expressed in terms of homographies and one circular inversion (Purushottam[57]).

van Dieren[15] studies properties of plane null systems. In an (n, m) system, $u_n=0$, $f(x, u)=0$, $a_x{}^m u_a{}^n=0$. An $(n, 1)$ system has n^2+n+1 singular lines.

Ditmarsch[16] maps the line elements (P, l) of a plane a upon the lines of space which touch a monoid. Let $M_n:O^{n-1}$ be a monoid with vertex at O, and OP meet it in R. Then r, the line of intersection of the tangent plane p to M at R and the plane (O, l) is the image of the element (P, l). The representation is (1, 1) with singular elements.

Sharpe[69] gives the various systems of curves for generating I_t in S_2. Particular I_3 in S_2 generated by means of a net of conics are given by Pomey.[56]

Another I_2 defined by the complex variable is given by Grace.[34] Let $f_i=0$ be a quadratic equation in z. If a_i is real $\Sigma a_i f_i(z)=0$ determines a (1, 2) correspondence between points a_i and points z_i.

The algebraic expression of the condition that the product of two involutions shall be an involution is given as an invariant by Browne.[6]

Algebraic space curves can be generated by means of a $(1, \gamma)$ correspondence between the congruences of bisecants of two space cubic curves having no point in common. This is also applied to congruences meeting a line c_i and a rational curve of order n which meets it in $n-1$ points. The curve considered is the locus of points of intersection of those ∞^1 lines of the congruence that meet their associates (Hulin [37]). Godeaux [29, 31, 32] continues the study of cyclic involutions belonging to algebraic surfaces. The differences between perfect and imperfect invariant points are made clearer by transforming them into curves (exceptional curves of the generating transformation). Particular attention is paid to transformation of period 11.

The idea is extended [30] to cyclic involutions on three dimensional varieties.

The image of a coincidence is a four-fold point on the image of the involution. The prime sections of the tangent primal cones is a surface of Veronese for I_2. For I_3 either a rational ruled surface of order 4 (normal) results, or it may have a nine-fold point, with prime sections of the tangent cone being the surface, image of plane cubic curves.

2. (2, n) correspondences. Periodic (2, 2) correspondences between two planes are considered by Edwards [18] by means of hyperspace. Given two planes in S_5 in (2, 2) correspondence. Join corresponding points, generating a V_3. Cut this by an S_4. The surface of section is invariant under two birational transformations. Conditions for periodicity are given.

A type of symmetric (2, 2) correspondence is given by Gherardelli.[27] The (3, 3) correspondences between two planes are derived and classified by Hollcroft [35] by means of their generating systems of curves.

Suppose an (l, l') point correspondence in the plane has a curve of fixed points. It is required to determine the number of its isolated fixed points, heretofore known only for the case $l=l'=1$. If of order n, the number x of such points is $x=n+l+l'-\mu-\delta+\gamma$, defined in terms of characteristics of hyperspace (Marletta [26]).

Further comments on the $(2, n)$ correspondence were made by Vycichlo.[84]

3. Double planes. Double planes with curves of branch points of orders 8 and 10 have been discussed by Campedelli.[10, 11] If C_8 has P_4, then $p=2$ and $P_2=3$. If C_8 has $2P_4$, $p=1$, $P_2=1$. These types had already been found by Enriques (1896). Various criteria for reducibility are discussed.

If C_{10} is nonsingular, $p_g=g_a=6$, $P_2=5$. Canonical curves are hyperelliptic, represented by double conics. In all, 28 types are discussed.

Johnson[41] gives the conditions that the Enriques' F_6, having the edges of a tetrahedron for double lines, can be reduced to a double plane with a composite double curve of order 8 consisting of two lines, a conic and a quartic or two lines and two cubics. In each case the surface belongs to three other involutions, making a non-cyclic S_4.

4. Methods of generation. Algebraic surfaces may have their canonical systems compounded with an involution. In the case of a curve having this property, it must be hyperelliptic. A surface may have its canonical system compounded with an I_n, $n>2$. An F_5 of S_3 with a tacnode is an example. Two other examples are given by Segre[68]; an F_5 of S_3 with two oscnodes with a double curve passing through both, $p_a=p_g=4$, $p^{(1)}=9$; I_4 and another F_5 of S_3 with two oscnodes, compounded with I_3.

Other systems compounded with involutions are noticed by Maroni.[49] If the canonical system $|K^*|$ is not invariant under Γ, then (a) with $|K^*|$ are two linear systems $|K_1^*|$, $|K_2^*|$ compounded with Γ, of dimensions r_1, r_2 and $r_1+r_2+1=p_g-1$; (b) every special complete linear system invariant in Γ is contained totally or partially in $|K_1^*|$ or $|K_2^*|$. A number of further properties are obtained.

Properties of curves and surfaces. The condition that a composite algebraic curve can be considered as the limit of an irreducible curve was considered by Albanese.[1] Each component has a Riemann surface. When they have been constructed for all the components and various cuts obliterated, the result is shown to be a Riemann surface. This is illustrated by pencils of cubics and by systems of $|C_6|:8P^2$.

Baker[3] gives an elaborate enumeration of characteristic conditions which satisfy the system of conics in S_3 which satisfy eight conditions.

Carnot's theorem concerning products of distances cut from a triangle by an algebraic plane curve has been extended to algebraic curves in space by Ichida.[38] The products are determined for the planes of a trilateral for curves that are complete intersections.

Cayley's problem of the in-and-circumscribed triangle of a plane C_4 has been studied by the methods of correspondences by Edge.[17] For a nonsingular C_4 the number is 288. The same method is then extended to singular C_4 and to higher algebraic curves with ordinary singularities.

Deaux[18] derives C_4, $p=0$ from C_4, $p=1$ of S_3. The pedal of a point with respect to a system of generators of a hyperboloid of one sheet and the line of striction is a rational C_4, obtained by means of two elliptic C_4. The methods of elementary projective geometry are employed.

Topology is employed to obtain the forms of real algebraic curves by Brusotti.[7] The curve consists of mutually skew circuits Σ and perhaps also of infinite branches. Conversely, every such system Σ admits an algebraic model. The method is that of small variations.

The moduli of a system of plane algebraic curves with given genus make a single irreducible entity. For $p<11$, it is rational. For $p<10$ the variable curve in a continuous system Σ, locus of linear systems having arbitrary base groups has particular moduli. If the moduli are general, the multiple points have restricted positions (Segre[68]).

Ichida[39] gives an elementary proof of Grace's theorem [Camb. Trans. 16 (1898)] on double sixes. The quintic symmetroid is defined as the locus of a point (x) in S_3 for which the primal $\Sigma x_i F_i = 0$ in S_4 is a cone, $F_i = 0$ being independent primals of order 2 in S_4. This can be written as a determinant $|ahg| = 0$, first column linear, second quadratic, third cubic. [Continued from Milne[52]; *see*[53].]

The projective generation of curves and surfaces in S_4 is considered by White.[91] Given two linear forms $\Sigma a_i \beta u_i = 0$, $\Sigma u'_i = 0$ in S_4, they generate V_3^3 with six double points. The F_6 common to two V_3^3 of system has a unique trisecant from every point of S_4. These lines project upon S_3 into a complex of order 8.

Pencils of linear complexes generated by projective systems of linear congruences are discussed by Deaux.[14] Milne[54] considers the contact conics of a quintic. Given such a C_2, 495 C_3 pass through the points of contact and touch C_5 in ten residual points at which it is touched by two further five-tangent conics. The method is to construct the canonical C_8, $p=5$, of S_4 and obtain systems of tangent quadric primals, then project into S_2.

The Steiner surface has an analogue in S_n. Let $x_i = u_i^n$, $i = 1, \ldots, 4$, each x_i being a linear function of three homogeneous variables. The equations define parametrically a rational surface of order n^2, having three lines of multiplicity n. If n is even, multiple lines are concurrent in a point of multiplicity $3(n-1)$ on the surface. If n is odd, the multiple lines are not concurrent, but coplanar, forming a triangle. If $n>2$, other double curves also exist.[92]

A linear element in S_2 is determined by the line element u and the point x, satisfying the condition $\Sigma u_i x_i = 0$. Put $p_{ik} = x_i u_k$. Then $p_{11} + p_{22} + p_{33} = 0$. In the matrix $||p_{ik}||$ all quadratic determinants vanish. These nine coordinates fix a linear element (P, l) in S_2. The p_{ik} are mapped on the points of S_8 (Schaake[62]).

5. Point groups on curves and surfaces. Comessatti [12.1] has given an interesting interpretation of Severi's series of groups of points on an algebraic surface, based on the notion of the characteristic series of a surface on a four dimensional variety V_4. The analogy of this to the characteristic series of a curve C on a surface Φ, which is known to be the difference between the canonical series of C and the series cut on C by the canonical system of Φ, might lead one to suppose the characteristic series of F on V_4 could be expressed by linear combinations of known series. It was shown by Segre [69] that it can not.

Hollcroft [36] discusses the involution defined by a web of surfaces $\sum_{i=1}^{4} \lambda_i f_i = 0$. $J(f)$ has $p_a = \frac{1}{3}(2n-3)(4n-5)(4n-7)$. Consider the map $y_i = f_i(x)$. Line in $y \sim C_n^2$, $p = (n-1)(n^2-n-1)$. This is well known for $n=2$.

The surface of branch points L of the involution and the Steinerian S of the web are reciprocal surfaces.

The M_3^6 of S_5, the image of the general cubic line complex of S_3, is irrational. If the complex contains three planes (or three bundles) it is birationally equivalent to the general cubic primal of S_4, and possibly is still irrational. Yet all the genera of M_3^6 are zero. It can be mapped on an involution of S_3. Both M_3^6 of S_5 and M_3^4 of S_4 are particular cases of M_3^{2p-2} of S_{p+1} (Fano [20]).

6. Double fives. Five lines of S_3 constitute a quintuple if each group of four among them have a single transversal. These five transversals also form a quintuple. The aggregate of ten such lines is called a double five.

The condition that a simplex can be inscribed in and circumscribed about a quadric three dimensional variety in S_4 is expressed by a symmetric determinant of order 6. A proper choice of signs of certain quadratic radicals leads to a consistent result (Segre [66]).

The same author [67] showed that this leads to a double five in S_3, proved in another manner by Weitzenböck.[88] The general theory of double fours and of double fives is given in the dissertation of Maurer.[57]

Gambier [24] applies the same idea to a system of circles and of spheres, including a metric generalization of the Morley-Peterson property to S_n; this was also applied to orthogonal systems by methods of pure geometry.[26] Another application [25] is made to the exceptional case $n=4$ in the problem of tangent cycles discussed by Tzitzeica [79] and Barbilian.[4] A new proof of double fives by parametric representation is given by Weiss.[87] Ciani [12] shows that the whole idea of double fives is due to him. [*Cf.* Ann. di Mat. (3) 8:1-21 (1902)]. An alternative proof for the characteristic property of a double five is given by Schaake.[62.1]

Fano[21] proves that an involution in S_3 is rational or irrational according as, considered as an algebraic three dimensional variety M_3, there is a finite continuous group of birational transformations under which M_3 is invariant.

7. Reducibility. Burniat[8] discusses a (1, 16) transformation in connection with a net of desmic plane quartic curves. Purushottam[57] and Stolzenberg[74] consider multiple correspondences between curves, defined by quadratic relations. Ragonesi[58] proves that the quadratic (m_1, m_2) transformations between two planes can be of indices (1, 1), (1, 2), (2, 2), (1, 3) and (1, 4) only. Veneroni[80] studies the symmetric (2, 2) correspondences under the restructive assumption that a general line of the plane contains one and only one pair of homologous points. The focal surface of a congruence of conics in S_3, defined by the incidence of homologous elements in a quadratic correspondence, is determined by Souris.[71-73]

Krames[43] employs quadratic transformations in connection with kinematic systems of circles. *See also* Federhofer[22] and Mayer.[51]

An application to non-euclidean geometry is made of (1, 2) transformations in S_2 and S_3 by Ota.[55]

Warnock[86] considers some of the groups of line configurations by determining transformations that leave the quadratic hypersurface in S_5 invariant. It is not exhaustive.

8. Application to lines, spheres, etc. The cubic line complex determined by the generators of the net of quadrics through eight points is discussed by Godeaux.[33] Particular nets may have more than eight singular points. Complexes defined in this way may have 8, 9, 10 or 12 principal points, but cannot have just 11.

Study[75] proposes a simplified and more logical basis for the Lie line-sphere transformation by replacing the two bilinear equations proposed by Lie by four such equations, denoting the planes (of one system) on Ω_4^2 in S_5, namely:

$$\begin{aligned} 0 + z_4\xi_1 + z_1\xi_2 - z_3\xi_3 &= 0, \\ -z_4\xi_0 + 0 - z_2\xi_2 + z_0\xi_3 &= 0, \\ -z_1\xi_0 + z_2\xi_1 + 0 - z_4\xi_3 &= 0, \\ z_3\xi_0 - z_0\xi_1 + z_4\xi_2 + 0 &= 0, \end{aligned}$$

and a corresponding one for the other system of planes.

Bennati[5] discusses two remarkable ∞^r complexes of S_4, one of lines and one of normal C_r.

Kol[47] defines congruences of conics in S_4 by means of enumerative geometry. James[40] associates complexes of conics in S_4 with the Weddle surface. A conic of the system, one through each point, meets a directrix C_6, $p=2$ in four points. Those conics of the system which touch a given S_3 have a Weddle surface for locus of points of contact. A Cremona transformation is determined. Through P passes one C_2 of the system and its four points on C_6 determine a pencil of conics. The polar lines of P as to this pencil meet in P'. It is $(4, 4)$: a plane is transformed into a surface of order 6.

Eiesland [19] defends the method of Lie as opposed to that of Study, maintaining that mistakes would have been avoided by a more careful use of the analysis involved.

A further study of complexes of spheres is made by Frank.[6] All the irreducible invariants of three quadric surfaces are directly interpreted as invariants of the concomitant linear complexes involved (Williamson [93]).

9. Systems of curves. (*a*) *Conics.* Calapso [9] gives a synthetic summary of a problem concerning the osculating linear complexes of conics to the asymptotic lines of a surface, usually treated by the methods of differential geometry. A metric application to obtain focal properties of a conic is discussed by Jonescu.[14]

Thomsen [77] raises the question: what is the largest number of singly infinite systems of conics possible on an algebraic surface? On a cubic it is 27, in the pencils of plane sections through the lines. Results are obtained largely by tensor analysis from the condition that each curve shall meet a line twice (de Vries [81.1]).

(*b*) *Cubics.* Godeaux [28] considers the congruence of space C_3 having five given bisecants.

(*c*) *Quartics.* (*a*) $p=1$. A congruence of elliptic space quartics is determined by five points and two skew bisecants. It can be generated by two pencils of quadrics and further curves of the system obtained by quadratic transformation (de Vries [82]).

The doctoral dissertation of Tol [78] treats various systems of elliptic space quartic curves.

de Vries [81] discusses two congruences of rational C_4 of S_3.

Kol [44, 45] derives various characteristics of systems defined by five points. The points are the vertices of a simplex, with regard to which the transformation $x'_i=1/x_i$ is employed. Lines are transformed into normal quartics through the vertices.

(*b*) $p=0$. A congruence of rational C_4 is generated by the residual intersection of cubic surfaces of a pencil and quadrics of a pencil, two fixed lines being common to both. This system was investigated by de Vries.[81] This author generalizes to congruences of rational curves of odd order, intersection of cones of two pencils, then mapped on the points of a plane through their vertices. For $n=5$, it is the congruence of Reye.

Schaake[62, 63] discusses ∞^2 systems through seven points and ∞^6 through five points, without further conditions. A study of the number of rational quintics through ten given points is given by the same author.[64]

Quadratic congruences of planes in S_4 were considered by Welchman[89] in connection with fifth incidence theorems. Given two curves C_4, C'_4, the planes that meet the first in three points, the second in one, also meet a third. These planes form a quadratic congruence. The C_4 may be replaced by two C_2; let two C_1 also be given, meeting both. The planes meeting all will meet another conic. The configuration is symmetric; there are three other systems of planes meeting three conics and two lines (Welchman[90]).

An extension of the theorem of the fifth associated line to spaces of more dimensions is made by Room.[60]

A transformation of the ∞^6 $|C_4|$, $p=0$ through five points can be made from the lines of S_4 by $x'_i=1/x_i$. These $|C_4|$ project into S_3 from a fixed point T. A curve C_4 through T of $S_3 \sim$ line of S_4 meeting a fixed C_4 (Schaake[64]).

An alternate discussion was given by Salmon-Rogers in Geometry of Three Dimensions, vol. I, p. 365.

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CHAPTER VI

SURFACES AND VARIETIES

AMOS H. BLACK

1. Cubics in S_3. An alternate proof of the property of a double six of lines on a cubic surface is given by Kubota [42] by methods of descriptive geometry. A totally different one was given by Todd.[84] Those double sixes whose cubic surface and cubic envelope are apolar are determined by Bishara [7] in a new way. The relation between a double six and its Schur quadric, in regard to which the pairs of double six are polar lines, is proved by elementary methods by Jolliffe.[41] The arrangement of the 27 lines in threes in the form of a determinant from which three double sixes can be at once determined, and from them the Schur quadrics, is given by Bishara,[8] suggesting some alterations in Dixon's earlier discussion. Desmic quartics are generated by the quadrics.

Piazzolla-Beloch [49] shows that C_5, $p=1$ on cubic surfaces have concatenated circuits. No quadric can have such curves but on surfaces of order >2 various curves of order 5 exist with this property; *see also.*[50] Timms [83] projects an F_2 of S_9 into S_3, giving all forms of cubic surfaces with a node. A systematic and comprehensive classification is included. In a somewhat similar manner, Roth[58] projects the apparent double F of a cubic manifold in S_5 upon S_4. This surface now has a triple curve and has improper nodes. These are the surfaces of S_6 which represent the congruence of bisecants of a C of S_3.

Various metric properties of the four-nodal cubic surface are described by Saddler.[68] Ursell [88] discusses the Cayley problem of seven lines; in symbolic notation the determinant of order 35 is expressed and reduced. The seven lines are mutually skew and the postulation of each is five. Given the seven lines, if three are selected, two elliptic C_6 can be found, having these three as quadrisecants and the other four as trisecants (Richmond [52]). The theorem of E. Toeplitz that, "if three quadrics are polars of three points as to a cubic surface, then their (2, 2, 2) invariant vanishes," is generalized to space of any odd number of dimensions by Anderson.[2] The method is that of algebraic symbolism.

2. Quartics and ruled surfaces in S_3. The ruled quartic surface with a non-composite cubic for double curve always belongs to a linear complex, which may be special or non-special, and has a finite number of torsal generators (Deweck[17]). The bisecant curves, that is, curves meeting every generator of a ruled surface twice, are further studied by Welchman,[90] extending the formula of Segre for such curves. The same author[89] generalizes the concept of incidence scrolls. In S_3, lines meeting three fixed mutually skew lines generate a quadric surface. In S_4, lines meeting five mutually skew planes generate a ruled surface $p=1$. Not all scrolls can be generated in this way.

Schaake[69] extends the formula for the order of the surface of trisecants of an algebraic curve of order n in S_3 to the case in which the curve has v_i points of multiplicity i and h apparent double points. The order of the ruled surface is $(n-2)\left\{h-\frac{n(n-1)}{6}\right\}+\frac{1}{6}\Sigma v_i i(i-1)(i-2)$.

Room[53] determines the quadrics with regard to which a rational scroll in S_3 is its own polar reciprocal. That ∞^6 correlations in S_3 transform a generator into a generator is not true (*see* Waerden).[91]

It is shown by Mathews[46] that the bitangents to a desmic surface at an arbitrary point on it are in two triples; those of one belong to a cubic cone and those of the other to its Hessian. Emch[23] uses the Geiser S_3 transformation on eight points to obtain some further theorems concerning the Weddle surface. Danielsson[16] considers a line $x_1y_1=x_2y_2=x_3y_3$ through the triple point of a Steiner surface. Any plane through such a line and a double line is always a tangent plane, with point of contact on the double line. The other tangent plane at that point describes a pencil as the point describes the line. Axes are conjugate in the quadratic involution of the bundle of lines. They coincide in four positions. At points where the lines meet F_4, tangent cones from them have plane C_4: 3 cusps for residual intersection.

By means of a quadratic transformation in the plane of projection of a Steiner surface from the triple point, a (1, 1) transformation leaving the surface invariant is obtained, expressed in terms of the projective lemniscate on it (Ciani[13]). The triple points of an algebraic surface are studied by means of quadratic Cremona transformations by Paul.[48] Danielsson[16] discusses double fours and double fives on a quartic surface having a double line or double conic. A plane C_4 has groups of eight double tangents which have the same property for $\infty^1 C_9$. There are four points through which two double tangents can be drawn. Wiman[95] expresses the tangent to a C_4, $p=1$ of S_3 by means of elliptic functions and considers the transformation $u'=u+c$. The locus of the intersection of osculating planes at corresponding points is an elliptic ruled surface of order eight. The tangent developable is included in the family, $c=0$.

It had been touched upon by Sturm (Verwandtschaften IV, p. 208), la Gournarie (Recherches, 1867) and Cayley [Camb. Trans. 11.2: 277-289 (1869); Edin. Trans. 25: 1-110 (1868)].

In 1892 Wiman, in his doctoral dissertation at Lund, gave a comprehensive study of sextic ruled surfaces. Various additions and alternate discussions have been made from time to time. He[96, 97] now comes back to the same subject and reconsiders the whole problem from the later standpoint. With the exception of a few tacnodal forms, supplied by Snyder (Am. J., 1901-1905), the earlier list was found to be correct. Although Snyder had no criterion for completeness, his list is the only one containing all the forms thus far found. With the new memoir of Wiman, the problem is thus completely solved. The most systematic treatment, arranging the results both as point loci and as envelopes, is that of Edge.[22]

The theory of isolated singular points of algebraic surfaces including an interpretation of the Zeuthen-Segre invariant $I=\delta-\sigma-4p$ for points of multiplicity higher than two, including uniplanar, tacnodal, etc., points was extended by Babbage.[3]

Turnbull[87] derives the condition that eight points in S_3 are associated without the use of a coordinate system. The result is expressed in algebraic vector symmetric form. A similar extension to surfaces having triple curves was made by Roth.[57] A three-dimensional variety has a double surface, triple curve, etc. Relations analogous to the characteristic of a surface in S_3 are derived. The double surface of a Del Pezzo variety must be ruled.

3. Quintic surfaces in S_3. The basic study of rational quintic surfaces was made by Montesano in a series of papers (1890-1915) by means of birational transformations of other known surfaces. Williams[92] obtains for certain of these surfaces the same results and some new ones by means of a different set of transformations. That having two distinct double lines is given in[93] and with the double lines approaching coincidence in.[94] In the latter case if the lines are coplanar, the surface is not rational but is rational when the lines are skew. Hubbs[35] considers all the rational quintic surfaces having no multiple curves. He confirms results obtained synthetically by Montesano and derives the equation of each type.

The 28 bitangents of a plane C_4 of genus three can be obtained from a net of quadric surfaces through eight points and the plane map of a cubic surface. The same method, applied to one dimension higher, gives the system of tri-tangent planes of a quintic symmetroid (Roth[56]).

It was shown by Fano[25] that the only surfaces in S_3 having projective plane sections are of one of four types: cones, quadrics, ruled cubics and the developable on the C_3 of S_3.

4. Sextic surfaces in S_3. Two papers by Souris[79, 80] describe sextic surfaces as focal surfaces of congruences of conics. Given a net of quadric surfaces with eight base points and a bundle of planes in quadratic correspondence with it, $\Sigma a_i \phi_i = 0$, $\Sigma \frac{x_i}{a_i} = 0$. Corresponding elements intersect in a conic, generating a congruence of order 2. Let the a_i be point coordinates in a plane (a). When two conics through P coincide, S_1 in (a) touches C_2 in (a). The locus is the focal surface. It is of order 6, has 45 conical double points and is the envelope of four systems of cubic surfaces of index two.

5. Configurations, surfaces and varieties in S_n. The general problem of the maximum number of lines that lie on a non-ruled algebraic surface is considered by Hollcroft.[32] Three categories are considered: independent, concurrent and coplanar. Dependent lines are illustrated but not completely classified.

Fano[26] finds that a configuration F_6 in S_5, discussed earlier by Baker,[5] is invariant under more collineations than indicated by Baker.

Welchman[90] extends Segre's formula to apply to curves meeting each generator of a scroll in hyperspace in two points. Todd[85] maps the system of $\infty^4|F_4|$ of S_3 through six mutually skew lines on the prime sections of a V_3^4 of S_4. It has 36 nodes instead of 20 and is determinantal. It defines a Cremona transformation of S_3 in which planes are transformed into surfaces of order 19 having the given lines five fold and other base curves. If the lines belong to a linear complex, the transformation is involutorial.

A system of lines in S_3 is said to be connected if it is possible to go from any line to the next and eventually back to the one started from. Points of intersection are not to be regarded as double points. If only consecutive lines meet and the last meets the first, a closed polygon with $p=0$ results. A necessary and sufficient condition that an n-lateral have $p=0$ is that it is simply connected. If $p>0$, the system is multiply connected (Piazzolla-Beloch[51]).

Involutions of points on an algebraic surface may be rational or irrational, except that irrational involutions do not exist on rational surfaces. It was shown by Enriques[24] that if on a regular surface, corresponding to an arbitrary n, n points can be chosen such that they all belong to the same group of I_n^r, $r \geq 2$, the surface is rational. If the given surface is irregular, it can be transformed into a ruled surface.

Maroni[45] generalizes the formula of Torrelli in various directions.

The number of apparent double points of surfaces and of varieties can be expressed when certain conditions are known. Those having but one apparent double point are determined by Edge.[21] Del Pezzo's quintic surface of S_6 is the only ruled example in S_5. Comessatti [14] considers the canonical series of an algebraic surface F. Let V be its variety of pairs of ordered points, Ω its surface of coincidences; the surface Ω is transformed into F. The characteristic series of Ω within V is the canonical series of Severi.

The surfaces of sectional genus 4 are classified into seven families of normal surfaces of hyperspace, by methods similar to those used by Castelnuovo for lower genera (Roth [61]). Lob [43] obtained the Clifford-Morley chain theorem by means of projection from higher spaces. By regarding the various terms of $|C_3|$ of a plane as point coordinates in S_9, loci representing various linear systems of cubics are discussed, with a sketch of its extension to C_n (Yerushalmy [100]).

By methods of differential geometry, Mentre [47] maps a quadratic line complex upon a non-special linear complex. The non-ordered pairs of points of a plane are mapped on the points of S_4 by Schaake.[70] Babbage [4] derives the rational double plane by means of a Veronese cone, that is, any cone in S_6 whose sections by $|S_5|$ are Veronese surfaces. The Geiser and Bertini types are derived and discussed.

The triple planes with branch curves of order not greater than 12 are discussed by Du Val.[19] If n is the number of sheets of a multiple plane with genus, by a prime section, π, then $2\pi+2n-2$ is the order of the curve of branch points. Let $\pi=0$. Then C_4 to be branch-curve of a triple plane, must have three cusps. The surface is rational; it is the projection of a ruled cubic form from a general line. If $\pi=1$, C_6 has six cusps on C_2, surface rational, or C_6 has nine cusps, surface elliptic. If $\pi=2$, C_8 is envelope of $\infty^1\{C_8\}$ index three, with 12 cusps. If $\pi=3$, C_{10} has 18 cusps, or 21 cusps. If $\pi=4$, the Grassmannian of projection must be from a restricted point.

The forms in S_r, $r>3$, may or may not contain planes. V_4 in S_r may have three, four, five or at most six. If V_4 contains six planes, and consequently 39 nodes, it contains a regulus with a generator in each plane (Roth [59]).

Du Val [20] constructs loci whose plane sections are elliptic. First, Segre's V_4^6, representing the pairs of points of two planes $\sim$ the congruence of lines meeting two planes in S_5. This can be mapped on S_4, by its trace of each S_1 of the congruence. The prime sections are represented by quadrics through two lines, traces of the directrix planes on S_4. Now let the planes approach coincidence. The problem was first studied by Scorza [72] and later by Timms.[83]

Particular systems of n-dimensional varieties containing n-systems of straight lines are developed by Barrau.[6] If x_1, x_2 are homogeneous point coordinates on a line, y_1, y_2 those of another, then $\xi_{ik}=x_iy_k$ determines a point on a quadric surface in S_3. In case of three, $\xi_{ikl}=x_iy_kz_l$ defines a sextic three dimensional variety in S_7. This is generalized to S_n.

The theory of correspondence as applied to curves is extensively developed but that of surfaces is still almost unknown, except for those invariant under continuous birational transformations, and certain involutions. The chief difficulty is not knowing valence on a surface. Albanese[1] considers two distinct algebraic surfaces, F, F' with general moduli, in (α, β) correspondence, and shows by transcendental methods that the valence is necessarily zero. On a surface of general moduli every correspondence is a valence correspondence.

The order of the double curve on the surface of trisecants of a given curve as given by Cayley (*Collected Mathematical Papers,* V, 187) and by Salmon-Rogers (*Analytic Geometry of Three Dimensions,* II, 97) is incorrect. Gambier[27] discusses types of singularities on ruled surfaces by means of plane birational transformations. Tacnodal and oscnodal conics may appear, which were not included in the classification of Edge[22]; *see also* Snyder.[78]

The harmonic ruled surfaces were found by Chiellini.[12] The hyperbolic paraboloid is the only algebraic surface. An additional note is given by Hilton.[81]

Relations among certain systems of curves enabled Segre[74] to determine a condition for regularity of a linear system of forms and of surfaces having their canonical system compounded with an involution. The varieties of Jacobi have geometric genus one and canonical variety of order two.

Severi[75] gives a comprehensive résumé of the foundations of algebraic geometry.

Sisam[77] shows that if through each point of a variety there pass just six right lines which lie on the variety, then the variety is a cubic hypersurface in four dimensions. The same author[76] gives the condition that a non-composite, non-conical three dimensional variety of order 5 be ruled. Roth[60] in studying ruled forms of four dimensions, distinguishes between those generated by a congruence, thus having ∞^2 lines, and those having ∞^3 lines, generated by ∞^1 planes. This is followed by a general study of possible types and a full set of references.

By a precisely similar method to Steiner's well known generation of the cubic surface, Roth[62] obtains from a polarity in S_n a rational form V_{n-1}^n, the points of which correspond to those of a given prime. The discussion is restricted to the four-dimensional case. Properties similar to those of Steiner are found; *see also.*[68] The same author[67] develops formulas concerned with the singularities of a primal in S_4 whose space section is a surface containing a double curve of general type; such a primal, therefore, has a double surface on which there is a triple curve containing a number of quadruple points. It is thus a particular case of the primal to be considered in developing the theory of reciprocal polars in four dimensions. In fact, some of the equations given are the first steps toward such a theory.

Schur's sextic is generalized to a higher space by Roth,[66] who shows that if the points of S_n are placed in (1, 1) correspondence with the quadrics of a given Σ_n in S_{n-1}, then to the cones of Σ_n correspond the points of a rational V_{n-1}^n. Room[54] represents the (self-dual) double-six on the Grassmannian manifold. There exist simplexes which at the same time are inscribed in and circumscribed about the manifolds in S_N whose points represent S_m's of S_n, where $N+1=\binom{n+1}{m+1}$. That in S_n there is one and only one normal rational curve osculating $r+4$ S_r's, where $n=r^2+4r+1$, was proved by Grace.[29] Room[65] proves the same theorem by a different method, with extensions.

A figure in S_9, consisting of 16 points and 16 S_4's, which can be derived from Kummer's configuration and which projects into it from a suitable chosen S_5 is discussed by Todd.[86] It is shown that all 16_6 configurations in S_3 may be derived by projection from the same figure in S_9 by a suitable choice of the vertex of projection.

It is shown by Hanumanta-Rao[30] that the planes of S_5 can be represented by the locus V_9 in space of 19 dimensions. This locus is a double locus on a certain other manifold V_{14}, and the tangent spaces of V_9 generate a W_{18}. Segre has a memoir [Ann. di Mat. 27: 75-123 (1918)] on the subject of these loci, in which he arrives at his results by a series of short steps.

In Segre's representation of the lines of S_3 by the points of a quadric in S_5, the chords of a rational C_3 are represented by the points of a Veronese surface V_2^4 lying on the quadric (where the V_2^4 is the map in S_5 of a plane by means of its conics). Brown[11] generalizes Segre's results. The S_k's of S_n may be considered as points of a (Grassmannian) variety. $V_{(n-k)(k+1)}$ in S_x, $x=\binom{n+1}{k+1}-1$. Those S_k's of S_n which are chordal ($k+1$ secant) to a rational normal C_n in S_n are represented by the points of a Veronese variety V_{k+1} lying in the Grassmannian variety (where the Veronese variety V_{k+1} is the map in S_x of an S_{k+1} by means of its $(n-k)-ic$ primals).

The number of $(q+1)$ – secant S_{q-1}'s of the non-developable varieties V_k^n which are rational loci each of $\infty^1 (k-1)$ – spaces is shown by Wong[98] to be $\binom{n-qk}{q+1}$ in a space of $qk+q+k+1$ dimensions. The number of apparent s-fold points on a $V^m_{(s-1)t}$ in S_{st+1} is finite. Wong[99] finds this number and also determines its upper and lower limits.

Roth[64] shows that a plane form is the locus generated by ∞^1 planes, and in four-dimensions is a dual construct of a scroll. An arbitrary space section is a scroll of general type in ordinary space, the enumerative properties of which have been exhaustively treated by James.[37, 38] Further a paper by James[36] on its dual form is complementary to the above paper. Together they give a complete account of scrolls and place forms in four dimensions. The last named paper depends on some formulas for the intersection of line systems in higher space found by James.[38]

Some formulas for multiple tangents and multiple secants of surfaces in higher space are found by Roth[65] by means of the "functional method." The same author[65.1] supplements the above work except that in plane of "functional method," formulas for multiple tangents to a surface in n dimensions $(4 \leqq n \leqq 6)$ may be deduced from the formulas for multiple secants by means of elementary correspondence processes.

The invariant postulation of a manifold of stated nature, but undefined position, on a hypersurface is discussed by Hollcroft.[33] The same author[34] uses the above method in finding the properties of hypersurfaces of order n in n dimensions. Properties of a general hypersurface of order four in S_4 are discussed in detail.

From differential geometry Sun[81] establishes certain properties of the curve of intersection of a surface and its tangent plane. The curve of intersection expressed parametrically is

$$\begin{aligned} y &= -2bx^2/3 - b_u x^3/6 - \ \ldots \\ x &= -2a'y^2/3 - a_u y^3/6 - \ \ldots \end{aligned}$$

It is the osculating nodal cubic. Takami[82] shows that if P', P'' be the two residual points of intersection of F_5 and a principal tangent at P on F_5, then the locus L of P such that $P = \frac{1}{2}(P' + P'')$ is a curve of order 200 which touches the parabolic curve of F_5 in 1200 points.

Segre[73] shows that there are projective transformations which preserve lines of curvature. By the transformation $x'_i = 1/x_i$ certain surfaces $\sim$ duals. Godeaux[28] maps the images of sections of genus zero by a system of F_4 and of F_3 on S_9. The Jacobian of $\infty^3 |H_2|$ is birationally equivalent to a double quadric having a curve of branch points of order eight.

A complete enumeration of the F_8 with an elliptic pencil of conics is given by Longo.[44]

The surfaces whose prime sections are hyperelliptic curves have been classified by Castlenuovo [Pal. Circ. Mat. 4: 73-88 (1890)].

Those of genus p are rational except ruled surfaces and two sheeted surfaces. There are exceptions for $p=1$. Such surfaces contain pencils of conics. Two plane representations $A \equiv |C_{p+3}| : P^{p+1}P^2$ and $(B_k) \equiv |C_{p+2+k}| : P^{p+k}kP^2$. Every (B_k), $k \geq 2$ is a special case of (B_{k-2}) and (B_1) is included in (A) (du Val[18]). Bronowski[9] shows that the theorem of Palatini [Torino Atti 41: 634 (1905-6)] must be modified.

Campedelli[11.1] shows that the theorem of Enriques that "if an algebraic surface has any linear system of curves of genus π, grade n, $n > 2\pi - 2$, it can be mapped on a ruled surface" is true without restriction.

Enriques[24.1] showed that elliptic surfaces $p_g = 0$, $p_a = 1$, with canonical curves of virtual order zero are distributed into seven families, representable on double, triple or quadruple planes. The surfaces of hyperspace with a triply infinite system of rational normal curves have been found by Bompiani.[8.1] They include two ∞^1 systems of rational normal curves C^v, $C^{v'}$ with $v + v' = \mu$, belonging to spaces of dimensions $(v+1)(v'+1) - 1$ and having the order $2vv'$. They represent plane curves of order μ with one multiple point of order v, and one of order v'. By means of the notation developed by Turnbull (Determinants, Matrices and Invariants), Saddler[68.1] considers various forms of the equation of a cubic surface. The envelope of a threefold cutting four lines in four points which lie in a plane is a cubic manifold. Some of the generalizations to higher space lead only to particular cases.

Consider the system of quadric surfaces expressed in plane coordinates, and having two essential linear parameters. They all touch eight associated planes. They intersect in pairs in C_4, $p=1$ all having the same cross-ratio, equal to that of the tetrahedral complex defined by the system of quadrics. (Danielson.[16.1]) Edge[22.1] maps the ∞^2 quadric surfaces of a net on the points of a plane. The cones $\sim$ points of C_4, in (1, 1) correspondence with a C_6 of S_3. The contact C_3 of C_4 associated with a tritangent plane of C_6 is an in-and-circumscribed triangle of C_4. There are eight such triangles of C_4 belonging to the system of contact cubics. The quadrics of the system having ∞^1 of index 2 envelope an octadic surface with the base points of the quadrics for nodes. de Vries[88.1] maps a monoid upon a plane by a central projection from its vertex; special discussions of orders 3, 4, 5. Roth[67.1] classifies the surfaces of sectional genus 5 and order 7 into 13 types. Those of lower order were known before.[57.1]

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